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SOVIET INSTRUMENTATION AND
CONTROL TRANSLATION SERIES

Measurement Techniques

(The Soviet Journal *Izmeritel'naia Tekhnika* in English Translation)

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PRESENT STATE OF GOVERNMENT CONTROL LABORATORIES IN THE FIELD OF MEASUREMENT TECHNOLOGY AND THE IMMEDIATE PROBLEMS CONFRONTING THEM

A. E. Viatkin

In accordance with the resolutions passed by the XX th Congress of the CPSU the growth of manufacturing in the USSR must be accompanied by its reorganization on the new technological basis and a determined effort to improve technological progress. A reorganization of manufacturing and building-industry controls, which removed departmental barriers and opened up these industries to local initiative, has created ideal conditions for the rapid introduction of the new technology into the national economy.

General technological progress depends on the development of measuring technology, as the introduction of new techniques, advanced technological processes and complex automatization of production are all intimately linked with the development of measuring accuracy, the development of new, more precise methods of measuring and the creation of new measuring devices which include those for the active control and complex automatization of technological processes and manufacture.

The national economy's equipment in the line of measuring technology increases rapidly from year to year and the nomenclature and the number of measuring devices based on the newest achievements of science and technology increase likewise.

In order to carry out succesfully the Party and Government decisions to introduce into the national economy the latest techniques, a properly organized and controlled measuring technology is absolutely necessary, if we are to eliminate unproductive losses and outlays and if we are to improve the general quality of production.

Our country operates a far-flung network of control laboratories in measuring technology, including 275 laboratories and their branches; all of these with the help of departmental supervision must maintain in proper working condition the available measurement equipment and see that it is properly used throughout the country.

In 1955 the Council of Soviet Ministers indicated the further need for both considerable improvement in the work of these organizations and a higher quality of scientific research papers on the development of new standards for various measuring units and ultra-accurate methods of measurement; it also recommended improvement in the material equipment and technical facilities of the institutes and the local branches of the Committee.

The Committee Order No. 617 of October 5th, 1955 and other instructions laid plans for the reorganization of the various Committee branches and for a major improvement in their work. One of these basic plans involved the reorganization, carried out by the Committee, of all local administrations into state control laboratories of measuring technology (GKL) in the hope of creating leading technical institutions able to solve important problems dealing with the improvement of measurement technology in their field; these institutions would thus cooperate in furthering our country's technical progress which depends to a large extent on measuring technology.

As a result of this order the number of higher-class laboratories increased greatly. From 1956 to 1958, 35 1st-class GKL's were established, 45 2nd-class and 55 3rd-class. In order to judge the scale and tempo of laboratory development it is sufficient to indicate that in 1955 the Committee system consisted of only 9 1st-class administrations and some of these, due to the lack of proper equipment were unable to verify a number of devices which should be checked by first-class laboratories.

The equipment of any laboratory should depend on the level and volume of the control work assigned to it both at the present level of the national economy development and that envisaged for the future in the territory assigned to the laboratory.

In 1956 and 1957 a large number of sample devices and pieces of apparatus were sent to the GKL; these included comparators, universal microscopes, optical comparators, apparatus for checking both radiation and optical pyrometers, thermostats with automatic controls, piston manometers, portable apparatus for checking differential-manometer flow meters, sample scales and weights of high denomination, tachometric devices, sample pendulum clocks, potentiometers and bridge devices, semiautomatic potentiometers, secondary frequency standards, sample apparatus for checking radio-measuring devices etc. 23.4 million roubles in all were spent on the apparatus and 27 million roubles have been budgeted for 1958-1959.

It is very interesting to note that 14 million roubles were spent by the laboratories in 1956-1957 for decentralized purchasing of equipment and for its modernization.

Local laboratories, taking advantage of a government order which permitted the directors of various companies and organizations to turn over material and equipment from their own stocks to Committee institutes doing inspection and research work, showed great activity and as a result obtained on the spot a great deal of valuable checking equipment (Tambev, Perm and other GKL).

As a result of these measures out of 35 1st-class laboratories 17 are completely equipped as befits their rank; 12 have from 80-100% of the necessary equipment and only one laboratory has less than 70% of the required equipment. Of 45 2nd-class laboratories 13 are completely equipped, 14 have from 80-100% of the necessary equipment and only 11 have less than 70%.

At the present time the Gorki, Irkutsk, Kiev, Kuibyshev, L'vov, Murmansk, Perm and Stalino GKL, VNIIK,* VNIIM,* the laboratories of the White Russian and Latvian SSR the Mordov ASSR and others are basically able to handle the demands of the local economies in checking standards and verifying measuring devices.

However, there are still very serious flaws in equipping the laboratories with proper checking apparatus. Certain GKL, in spite of the existing opportunities still do not have to their best advantage the means at their disposal for decentralizing purchase of equipment: Arkhangelsk, Astrakhan, Gorki, Krasnodarsk, Orenburg, Cheliabinsk, Iaroslav, and also the Azerbaijan and Armenian SSR. Local GKL (Vladimir, Magadan, Omsk, Stavropol' and others) take an unreasonably long time to put into operation equipment locally obtained.

Recently a great deal of attention has been given to the establishment of mobile checking laboratories and in 1956 and 1957 the GKL obtained for this purpose 250 automobiles (GAZ-69); 150 of these were completely equipped as mobile laboratories while the majority of the others were partially equipped. Moreover local branches of the Committee equipped 32 GAZ-51 automobiles as mobile laboratories. The use of these automobiles made it possible to extend the checking of measures and apparatus directly at the spot where used, thus reducing the expense of the measuring and checking work carried out by the GKL. Thus, according to communications from the Altai , Andizhan, Vladimir, Voronezh, Ivanovo, Novgorod, Samarkand, Tashkent, Chernigov and other GKL and also NGIMIP, these mobile laboratories have cut in half the time spent in inspecting agricultural regions.

However, a number of laboratories do not take advantage of the checking and inspecting services of the mobile laboratories. At the present time the Altai, Astrakhan, Kursk, Perm, Cheliabinsk laboratories and also the Tadzhik and Turkmen SSR, Komi ASSR and many others have not equipped a single automobile in their possession.

The normal work output and development of the GKL depend largely on available working space. This problem has been solved in two ways: by the construction of special buildings for the GKL by the Committee and the use, through local authorities, of available local housing. In 1956-1957 the Committee erected new buildings for 10 laboratories and 4 departments while Oblispolkom* local committees provided housing for the GKL in 19 towns and for permanent departments of the GKL in 39 towns. The Amur and Astrakhan GKL and also the laboratories of the Armenian, Lithuanian and Ukrainian SSR were very active in the field of laboratory housing.

As a result the work production of the GKL and their permanent departments increased by 84% in the last two years as compared to 1955.

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* See Russian Abbreviations, A Selective List, Library of Congress, Washington. VNIIM is the All-Union Scientific-Research Institute of Metrology; oblispolkom is the Regional Executive Committee.

At the present time buildings are being erected for 17 GKL of which 7 will be finished this year and 10 next year. The Committee has likewise drawn up a laboratory building plan for 1959-1965 which will solve completely the question of laboratory housing.

The selection, training, preparation and assignment of personnel is of primary importance in the operation of Committee institutions.

During 1956-1957 more than 500 employees were hired having secondary and higher scientific training; the number of specialists with higher education among the directors of the GKL has increased by 50%; approximately 250 young specialists, having finished secondary and higher technical institutions, have been assigned to this work; in 1958 the number of employees in GKL studying at secondary and higher evening and correspondence schools increased to 700 (282 of them attending higher institutions) as against 400 who were studying as the 1st of January 1956.

The Ukrainian SSR laboratories have worked diligently on the improvement of their personnel; 62% of the engineering positions were held by employees with a higher technical education and 60% of the employees having no technical education were enrolled in correspondence courses.

In 1956-1957 a number of measures were taken to increase the qualifications of the operation staff of the laboratories and in the majority of the GKL local scientific instruction has been intensified.

However, judged as a whole, the GKL personnel work can not be termed entirely satisfactory. Thus, for example, the positions of assistant senior engineers and engineers in a number of laboratories and institutes are not properly filled. This is the case in the White Russian, Kazakh, Tadzhik, Turkmen, Uzbek SSR and in a number of RSFSR laboratories.

Only 32.8% of the employees having no special education are enrolled in correspondence or night schools. The situation is particularly bad in the Kazakh, Kirgiz, Moldavian and Tadzhik SSR, where only 12-19% of the employees not having a secondary technical education are enrolled in correspondence courses. However the last few years have shown that the most effective way of increasing the qualifications of employees with no technical education is to have them take correspondence or night school courses at secondary or higher technical institutes. This must be kept in mind both by the directors and the employees of our laboratories.

The level of GKL activity depends considerably on the scientific research work carried out by the Committee institutes. During the past two years the institutes have, generally, speaking, eliminated the lag felt in certain fields of measurement in the national economy and in metrological studies as compared to similar work abroad and in certain fields of measurement the institutes obtained better results than those obtained abroad. Thus, for example, standard determinations of datum points for the international temperature scale, units of mass and length, electric and magnetic magnitudes, pressure, force, time and frequency are carried out at the same level in the Committee institutes as in the leading metrological institutions of other countries.

When the USSR government standards were compared with their copies at the International Bureau of Standards and Weights the results were excellent, proving the high level of standard studies in the USSR.

In 1957 the Committee institutes developed 36 new methods of measurement, established 5 values of constants, carried out 73 investigations of various physical processes and built 82 new sample and standard devices, thus increasing considerably the metrological services of the national economy.

Institute aims were changed considerably during 1956-1957 under the leadership of GKL. They became largely concerned with supplying technical assistance directly on the spot by sending qualified institute employees to the GKL, in particular when introducing new checking apparatus and new checking methods. Moreover, the institutes organized a training program for many GKL employees in this field.

Among the failings of the institute activities, other than the lag in certain specific fields of measurement, the most serious is the inefficient application of institute research studies; two or more years invariably elapse before techniques developed at the institutes are put into effect.

The importance of GKL as organizing-technical centers considerably increased in 1956-1957 as a result of the measures taken to improve the quality, the equipment, the housing and the staffs of the laboratories, the clarification of their aims and an increase in the help and leadership of Committee institutes.

Many laboratories have carried out on their own initiative useful measures toward the improvement of the means of measurement; they introduced new means and methods of measurements; they organized an exchange of information in the field of measuring technology, made recommendations and offered practical assistance to various concerns on the improvement of technological process controls, studied methods of lengthening the life of apparatus and helped in the training of factory laboratory employees. Among these are the Vladimir, Voronezh, Zaporozhe, Ivanovo, Kiev, Krasnodar, Kuibyshev, Khabarovsk, Cheliabinsk, the Azerbaijan, White Russian, Latvian and Lithuanian SSR and also VNIIK, VNIIM and KhGIMIP.

However, many GKL are still insufficiently active in introducing new methods of measuring technology. The Archangel, Belgorod, Magadan, Murmansk, Novgorod, Omsk, Orenburg, Orlov, Penza, Pskov GKL and also the laboratories of the Bashkir, Dagestan, Komi, Mari and Tatar ASSR are in that class.

Experience has shown that in the districts where the local branches of the Committee duly carried out the plans and decisions of the local committees and the Council of Soviet Republic Ministers in the field of measuring technology, where they checked their progress, daily, where they worked constantly for the improvement of the means of measurement, developed and improved departmental controls and supervision, and organized a department of maintenance and upkeep, the general situation considerably improved (Vladimir, Gorki, Ivanovo, Kiev, Kostroma, Kiubyshev, Murmansk, Khabarovsk laboratories; also VNIIK, the Sverdlovsk branch of VNIIM and a number of other laboratories). On the contrary in the districts where the GKL did not pay sufficient attention to all these problems many measures and decisions were not carried out (Penza, Perm, Primorsko, Pskov, Riazan, Tambov laboratories and also that of the Lithuanian SSR and the Komi and Tatar ASSR and a few others).

Local branches of the Committee likewise increased control of measuring technology by means of a general revision of the state of measures and measuring devices presently in use. In 1955, 14,328.7 thousand measures and measuring devices were inspected; in 1956, 17,380.9 thousand and in 1957, 16,218.8 thousand which is 121% and 113% respectively of the 1955 total. The results of the inspection were tabulated and methods of eliminating the defects noted on inspection were brought to the attention of both the directors of the organizations and the regional executive and regional committees of the Communist Party of the Soviet Union.

As a result of the work carried out in 1956-1957, 1572 branches of departmental supervision were once again organized and by 1958 there were 8,700 branches of departmental supervision, 1300 open workshops for the maintenance and upkeep of measuring apparatus, 5,000 closed workshops and 730 organizations carrying out technical inspection of measures and measuring apparatus on contract.

The results of inspections show that the state of measuring technology has improved as the amount of unusable measures and apparatus decreased from 8.7% in 1955 to 3.7% in 1957.

Since it is now always possible to detect production or structural defects by means of a state inspection for quality control at plants producing apparatus, the Committee instructed the GKL to organize a study of the working properties of measures and apparatus being acquired by different concerns and organizations. This study was carried out during 1957 by a majority of GKL and included over 100 different types of apparatus. The results of these studies enabled the Committee and the GKL to make proper suggestions to the apparatus-building concerns for the improvement in the quality of their product, as a result of which more than 50 different types of apparatus were greatly improved. Good work was done by the Zaporozhe, Ivanovo, Kiev, Krasnodarsk, Leningrad, L'vov GKL and by the laboratories of the Latvian, Lithuanian and Kirghiz SSR and others.

However, some local GKL were carrying out either incomplete or formal studies and did not use the material available on apparatus manufactured and experimentally controlled in a district subject to inspection; such inspection work had been carried out in order to bring before the manufacturer and the Council of National Economy questions concerning the improvement in the quality of the apparatus.

However, one of the most flagrant defects in the operations of all the GKL in the field of measures and measuring apparatus is the fact that they do not use the wealth of material presented by governmental checks and inspections. GKL limit themselves to the registration of facts simply stating that a certain measure or apparatus is defective without giving any reasons for it; they do not analyze or generalize the data. It would seem that an engineering study of such material would permit the GKL to give much needed assistance both to the buyers and the manufacturers of apparatus by pointing out to them the defects in construction, the individual manufacturing problems and quality of the production. GKL should plan to carry out such studies and activities.

In carrying out the resolutions of the July Plenary Session of the Central Committee of the Communist Party of the USSR (1955) for increased control over government standards and technical conditions, the Central Committee increased considerably this type of work, with the cooperation of the GKL's, which were given the task of eliminating on the spot the defects and infractions that might come to light during an inspection.

Inspection work carried out at various concerns has now taken on considerable magnitude and, at the present time, extends to the great majority of districts, regions and republics. In 1956, 1083 enterprises were inspected and in 1957, 1014, as compared to the 261 in 1955.

In certain cases the results of the inspection were reported by the Committee to the Council of USSR Ministers and to the directors of the ministries and departments of the USSR. The Council of Ministers, acting on the reports of the Committee, gave directions concerning the elimination of infractions and defects.

The directors of the GKL in many cases showed commendable initiative and carried out analogous measures on the spot, reporting directly to the Council of Ministers of the Soviet Republics, to the ministries of the republics to the Council of National Economy (Sovnarkhoz) and also to the party organs recommending improvements in the quality of production and in the general state of measuring technology.

As an example of this we can point to the work carried out by the Moldavian SSR laboratory in relation to inspections and control of the food industry. By analyzing and standardizing inspection procedures and results the laboratory was able to bring to the attention of the Council of Ministers of the Republic possible improvements in the quality of production and in the state of measuring technology.

A number of other laboratories also carry on consistent studies in the field of inspection and control reaching a maximum of efficiency in the elimination of various defects. (Zaporozhe, Kostroma, Stalino, Khabarovsk and other GKL). The initiative of the Kostroma laboratory is to be highly commended; the laboratory organized a control of drinking water and bread, producing excellent results.

However, a great number of GKL are carrying on this important work at a very low efficiency level, do not give it sufficient attention at its various stages and as a result the practical advantages of inspection and control as carried out by these laboratories is very small (Krasnodar, Omsk, Penza, GKL and the laboratories of the Armenian, Kazakh SSR and the Tatar ASSR and others).

These unsatisfactory results are due to poor organization when inspection, and control are entrusted to personnel unfamiliar with the products to be inspected, and specialists from the Sovnarkhoz and departmental inspectors are not called in; they are also due to a poor choice of enterprises to be inspected, or the inspection of enterprises which handle materials for general public consumption where systematic departmental inspections and controls have been already set up, thus, neglecting inspection of enterprises handling machine tools; they are also due to a lack of efficient control because of the absence, in many cases, of a necessary and systematic inspection of the enterprises to see if they are carrying out the suggestions brought about as a result of the inspections.

Measures undertaken by the Party and the Government in connection with the further development of the national economy on the basis of new technology necessitate on the part of the state control laboratories of measurement technology an improvement in state control of measures and apparatus; this can be done by helping organizations and enterprises check their means of measurement and also by assisting them in every way possible with all of their problems concerning measuring technology; simultaneously an effort should be made to decrease the costs of state and departmental inspection and control of the means of measurement.

In connection with this we are faced with a number of problems demanding immediate solution.

The state control laboratories in measuring technology and the Committee institutes must not only take care of all the demands of national economy in the field of measuring technology, but should also be leaders in that field; they should introduce, establish and organize new technology, they should wage a constant and unrelenting battle to reduce production losses due to the use of poor, incorrect measures and apparatus and violations of standards and technical conditions; they should organize, strengthen and develop departmental supervision; they should organize an exchange of information and popularize new methods and means of measurement; they should improve the quality of the produced measures and apparatus and should remove from the organization uncooperative elements; they should organize the maintenance of measurement apparatus and generally supervise the improvement and development of measuring technology in our country.

Greatest efforts of the GKL should not be directed towards the "legalizing" of measures and apparatus;rather, the GKL should make certain that these measures and apparatus are in proper working condition.

The local branches of the Committee should make maximum use of the particularly advantageous conditions created by the reorganization of the Departments of Commerce and Building, should work more closely with the Sovnarkhoz, with the party and government branches of the republics, departments and towns, and ask for their cooperation in the improvement of measuring technology within their individual juristictions. GKL and the institutes must carry out as soon as possible the plans already recommended by the local and regional Executive Committees and the Council of Ministers of the allied and autonomous republics; they should report to the latter the results of their inspections and should introduce measures for the rapid fulfillment of these plans.

The GKL will be able to handle these problems effectively when they themselves become proper examples of departmental measuring laboratories, when they are properly equipped with modern measuring apparatus, are able to produce a high quality of work and have properly trained and organized staffs. Directors of all local branches should be working constantly with this aim in mind. Directors of GKL whose development is slowed down by the lack of proper working space, should demand of the local authorities immediate improvement in the laboratory housing situation.

Special attention should be given to improving the personnel, and increasing their qualifications. The Seven-Year Plan proposes to increase the number of engineering positions in the laboratory to 40-50% of the total number employed and measures have been drawn up to improve their qualifications. In the very near future the Committee system will be unable to employ personnel who lack proper education, do not improve their qualifications and therefore, do not have the necessary requirements for employment in state control laboratories in the field of measuring technology.

In accordance with instructions laid down by the Council of USSR Ministers, the Committee has developed a plan on standardization and metrology for 1959-1965; this plan envisages further development of state control of measures and measuring devices and includes the organization of 9 interregional base laboratories in Alma-Ata, Irkutsk, Kiev, Kuibyshev, L'vov, Minsk, Tashkent, Tbilisi and Khabarovsk. These laboratories will take over to a great extent the functions of the Committee institutes checking standard measures and apparatus, training personnel in measuring technology and offering technical assistance to the laboratories within their territorial jurisdiction.

In view of the economic growth of departments, regions and republics,plans have been made for 12 additional 1st-class laboratories, 25 second-class laboratories and 30 third-class laboratories.

In response to the demands of various enterprises and organizations, 60 laboratories located in large commercial centers will have additional facilities for repairing and adjusting operations available to outside organizations and employing approximately 1000 people.

In order to answer best the various problems of the national economy when dealing with the checking of measures and measuring apparatus, the plan forsees a marked development of GKL activities,opening new fields for measuring technology and introducing new methods and new apparatus and improving the accuracy of measurements in the already existing fields.

Some fields in which at the present time no measurements are carried out, or by one laboratory only, are dosimetric, acoustical and hydroacoustic measurements, radiant-energy measurements and others.

The production of each department of the Committee will be judged by the success and rapidity with which it is able to solve the above problems by its own initiative.

The establishment of standard units of measure and accurate measurements in all branches of our country's economy is the principal aim and reason for the improvement and reorganization of the GKL and the Committee institutes.

At the present time, especially after the reorganization of commercial and building industries, specialization of various enterprises and their cooperation with each other have become increasingly important; of equal importance is the introduction of complex, mechanical production methods based on interchangeability of parts. It is obvious that in order to have corresponding parameters and standardized production correspondence of technical conditions

and blueprints, interchangeability of parts produced by different enterprises, it is absolutely necessary to maintain standard units of measure and accurately produced measurements. Therefore, all the Committee institutions must be constantly on the alert in order to give all necessary assistance to any organization in need of help in the field of measurement technology.

These problems can be solved only when all members of the personnel of the Committee system realize the importance of their work and its place in the national economic system.

The government of the USSR has given the Committee system personnel a remarkable opportunity to eliminate serious operational defects. It is the duty of all the Committee workers, employees of Committee institutes and GKL with the help of Party, Soviet professional and Komsomol organizations, to make the best use of these opportunities in order to best serve the national economy by establishing and preserving standard units of measure and accurate measurements.

ON THE NEW DETERMINATION OF THE METER

G. D. Burdun

One of the most important questions in the contemporary development of metrology is the question of a new determination of the basic unit of the metric system – the meter.

When the metric system was established, its unit of length was taken as one ten-millionth part of the quadrant of the meridian passing through Paris. A direct measurement of the section of the Paris meridian from Dunkerque to Barcelona undertaken by French scientists made it possible to establish a unit of measure and to prepare a standard-prototype in the form of a platinum bar which at the end of the XVIII-th century was turned over for safekeeping to the French Government Archives and was given the name of "the archive meter."

However other measurements of the meridian showed that the length of the archive meter is somewhat less than that of the "natural" meter. As with further more accurate measurements different values for the basic measure of length were obtained, the First General Conference on Weights and Measures in 1889 decided to take for its standard unit of length a specially prepared platinum-iridium engraved bar, which was known as the "international prototype of the meter" and within the limits of attainable accuracy was equal in length to the archive meter. Thus, the meter lost its significance as a "natural" measure.

The development of physics at the end of the XIX-th century brought about the possibility of a return to the natural standard of a unit of length. On the basis of the work done at the International Bureau of Weights and Measures by Michelson and Benoit, the Second General Conference on Weights and Measures in 1895 decided to take as a "natural prototype of the meter the relation of the meter to wave lengths of light." Further studies, carried out in a number of laboratories in different countries, led to the possibility of establishing a natural standard of length as the meter expressed in wavelengths of light (light meter). The following radiations were suggested as possible standards: yellow sodium line, then the green line of mercury, finally the red line of cadmium.

In 1927 the Seventh General Conference on Weights and Measures legalized the numerical relation between the meter and the wavelength of light. The meter was taken to be equal to 1553164.13 wavelengths of the red line of cadmium, when radiating under standard conditions.

Later new studies were carried out at the metrological institutions of many countries on the creation of standard sources of radiation using isotopes which produce narrow monochromatic lines. In Germany studies were carried out with isotopes of krypton Kr^{84} and Kr^{86}, in the USA with isotopes of mercury Hg^{198} and in the USSR with an isotope of cadmium Cd^{114}.

In 1948 the Ninth General Conference on Weights and Measures passed the following resolution: "The General Conference on Weights and Measures, taking into account new possibilities opened up by the spectrum

lines from single isotopes, combining in the highest degree the properties necessary for the creation of standard wavelengths salutes the scientists whose studies made considerable amounts of these elements possible; it admits that in these lines lies the possibility of finding a natural basis for the accuracy of the unit of length; it invites the principal laboratories and the International Bureau to continue the study of these lines with the hope of establishing in the future a new determination of the meter based on the wavelength of a chosen line emitted under specific conditions."

The International Committee on Weights and Measures in 1952 created a special advisory committee on the determination of the meter. This committee, having studied the reports of the various large national metrological laboratories on the light meter and having announced at its first session in 1953 that the time had come to look favorably upon a new determination of the meter based on the length of the light wave was unable, however, to limit its choice to one standard radiation as possessing the best metrological properties and admitted the necessity of continuing with its work on monochromatic radiations.

At the first session of the Advisory Committee the following 6 resolutions were passed:

Resolution I. "The Advisory Committee on the Determination of the Meter having heard the reports of the Director of the International Bureau of Weights and Measures

1) on the accuracy with which, at the present time, the basic unit of length in the metric system is preserved by means of the platinum-iridium standard and

2) on the accuracy which one is able to achieve at the present time by means of engraved standards, assumes that the time has come to examine favorably a new determination of the meter, based on a wavelength of light so that the unit of length would have both a greater accuracy and would posess an indisputable nature of universality and nonperishability."

Resolution II. "The Advisory Committee feels that when the time comes the meter must be determined by means of a wavelength of light radiation, emitted in a vacuum, the emitter and the observer being relatively at rest.

This radiation must be determined by two spectral terms of an atom whose spectrum is devoid of hyperfine structure and which is not subjected to any disturbing influence."

Resolution III. "In order to guarantee for the unit of length as complete a continuity as possible when changing to the specified determination, we recommend that the latter be fixed at the intermediate value $0.64384696 \cdot 10^{-6}$ m for the wavelength of the red radiation of cadmium, as was specified by the Seventh General Conference on Weights and Measures.

For this transition period the reduction to vacuum of wavelengths which have been measured in air must be carried out by means of the dispersion formulas for normal air, adopted in Rome in 1952 by the Combined Committee on Spectroscopy."

Resolution IV. "As for the choice of a standard radiation posessing the best metrological properties (width of line, symmetry etc) the Advisory Committee believes that there is not enough documentation at the present time to make a definite recommendation. It suggests that the large laboratories and the International Bureau continue as actively as possible their studies in that field."

Resolution V. "Assuming that the determination of the meter is to be changed, the Advisory Committee on the Determination of the Meter recommends that the International Bureau of Weights and Measures be equipped with the most accurate devices and apparatus for carrying out interference measurements in a vacuum in order to determine, under optimum conditions, the relation between the wave lengths, the engraved standards and the archieve type standards and thus carry out one of the principal missions entrusted to it by the Metrical Conference; the Advisory Committee is convinced that the mission of the International Bureau of Weights and Measures must remain, as heretofore, a basic one in the realm of length measurement."

Resolution VI. "The Advisory Committee recommends that the International Committee ask the General Conference, which is to meet in 1954, to grant it the necessary powers so that it can decide on the order and date of the change without waiting for the next General Conference."

The Tenth General Conference on Weights and Measures having studies and discussed the report of the Advisory Committee on the Determination of the Meter and the reports of the national metrological laboratories

on this question admitted that there is still no possibility of making a choice between spectral lines and decided to retain the former determination of the meter until the Eleventh General Conference on Weights and Measures to be held in 1960.

The October 1956 regular meeting of the International Committee of Weights and Measures, Professor J. Terrien, the vice-director of the Bureau gave a report on the work done by the International Bureau on monochromatic light sources for the reproduction of a unit of length by means of light waves. Light sources were studied which were filled with the isotopes Kr^{86} (presented by the USA National Bureau of Standards) and Cd^{114} (presented by the D. I. Mendeleev Institute of Metrology, USSR). These studies showed that the spectrum line shapes from isotopes, and in particular the red line of Cd^{114}, the yellow-green and orange lines of Kr^{86} and the green line Hg^{198} are simple and symmetrical. However a thorough study of Hg^{198} and its green line showed that even at a light-source temperature below 20°C self-reversal is observed. A broadening of the line is also observed under the influence of external conditions. The study of the Cd^{114} tube showed that the red had a symmetrical contour and that the green line showed self-reversal. A certain relation between the temperature of the source and the wave length of the red cadmium line was observed, apparently linked to a change in the pressure in the tube. Krypton lines were studied; they were narrowest when cooled to the temperature of the triple point of nitrogen.

For all three isotopes (krypton, mercury and cadmium) the width of the spectrum lines was 35% wider in actuality than in theory, which can not be explained by the effect of the discharge itself; further studies will be necessary.

Studies at the laboratory of the International Bureau of Weights and Measures were carried out by a photoelectric method. As a result of these studies it was shown that the orange line of Kr^{86} is the narrowest (13 μ) and therefore at the present time seems to form the best basis for a future determination of the unit of length.

The International Committee on Weights and Measures found it necessary to continue work in this field and in particular to carry out an exchange of light sources between various laboratories in order to study as thoroughly as possible all metrological properties of the sources.

The second meeting of the Advisory Committee took place September 23-25, 1957 at the International Bureau of Weights and Measures. Representatives of the largest metrological laboratories of the world attended this meeting: Barrell (National Physics Laboratory, England), Belie (National Institute of Arts and Crafts, France), Gardner (National Bureau of Standards, USA), Govlett* (National Scientific-Research Council, Canada), Perukka (National Institute of Metrology, Italy), M. F. Romanova (All-State D. I. Mendeleev Scientific-Research Institute of Metrology, USSR), Tamano (Central Control Institute of Weights and Measures, Japan), Terrien* (International Bureau of Weights and Measures), Schtulla-Getz (Federal Bureau of Weights and Measures, Austria), Edlen (Lund University, Sweden), Engelgard (Physical-Technical Institute, FRG).

The chairman of the Advisory Committee, Prof. Govlett noted that the reports presented at the meeting contained valuable material on the study of various monochromatic light sources that will play a large part in the solution of the problem before the committee.

The first report was that of the director of the International Bureau of Weights and Measures, Sh. Volle; he indicated that the results of the recent comparisons of the International Bureau meters and the meter prototype agree very poorly with the results of the 1938-1939 comparisons. It follows that the international prototype was determined with an error of not less than 0.1-0.2 microns.

A correspondence of better than 0.1 microns is obtained with the engraved meter, but it is very difficult even now to obtain perfect engravings. Therefore, instead of improving the determination of the unit of length by means of new engraved standards it seems more expedient to adopt a natural standard such as a light wavelength.

In 1953 the International Bureau expressed concern about the adoption of a "light" meter. However at the present time it is possible to compare various wavelengths very satisfactorily and it is also possible to affect the direct transfer from a wavelength to an engraved standard; several laboratories are equipped with comparators making such transfer possible and the International Bureau has such a comparator ordered to be installed within the next two years. At present the International Bureau no longer sees any insurmountable difficulties in effecting this transfer if a continuity of the unit of length can be guaranteed.

The reports of the Physicotechnical Institute (FRG) stated that a method of thermodiffusion was used to separate the isotopes of krypton, in particular Kr^{86}; this method produced a 99.5% pure Kr^{86} in sufficient quantities to fill 1000 tubes. An improved separation method will produce a 99.7% pure Kr^{86} in considerable quantities and at low cost.

The Physicotechnical Institute carried out vacuum measurements on light wave radiations, which were of the greatest interest to the Advisory Committee. The wavelength of the red cadmium radiation was determined (using Edlen's dispersion formula) and the wavelengths of the most important radiations of Hg^{198} and Kr^{86} were likewise determined; the orange line (0.6056 μ) of the last named element was accepted as the best. This radiation attains within the tube a brilliance differing but little from that of the red radiation of a cadmium in the Michelson tube. Corrections were made which mast be introduced into the results in order to bring them to the "ideal" state; zero pressure, zero current and zero atomic velocity.

Analogous measurements were carried out in other laboratories but the results obtained show systematic differences. These must be attributed largely to the Michelson lamp, whose specifications do not guarantee the reproducibility of results demanded by contemporary measurements.

The Physicotechnical Institute also studied other elements with the aim of producing monochromatic radiation, for example Xe^{136}, Ne^{20} and Th^{236}, excited at the temperature of the triple point of nitrogen, whose mass is even and high. It was concluded that krypton best satisfies all the necessary conditions due to the ease with which its extremely monochromatic radiations can be produced.

The National Bureau of Standards (USA) preferred, as a result of its studies, the green radiation (0.5461 μ) of Hg^{198}. Means of producing this mercury are well known and it can be produced in several countries. The electrodeless-discharge Meggers tube using Hg^{198} excited by a high-frequency field has a long life and its operation at normal temperatures is an additional important advantage. The noise level of the tube may be decreased to 0.1% of the total signal noise which is convenient when using a photoelectric detector.

The inconvenience brought about by the self-reversal of the line may be eliminated by substituting nitrogen for argon as the carrying gas, as was proved by the research carried out at the National Scientific Research Council of Canada. Finally it is hoped that a higher degree of monochromaticity may be obtained by using Hg^{198} as an atomic beam; this is not being studied.

For this reason the National Bureau of Standards proposed to defer the final decision until the next meeting.

The National Physical Laboratory (England) reported on recent vacuum determinations of the wavelength of monochromatic radiation. The measurements were carried out photographically by means of the Fabry-Perot standard. The most difficult to measure was the red radiation of natural cadmium using a Michelson tube, because of the considerable line width in which are found traces of isotope structure and asymmetry. In contrast the lines of Kr^{86} radiation are sharp and can be measured with great accuracy.

Although the National Physics Laboratory did not deny the fact that the Hg^{198} tube is very useful and will doubtless be used along with the Kr^{86} tube it agreed wholeheartedly with the opinion that at present the Kr^{86} radiations are the best.

The D. I. Mendeleev All-State Scientific Research Institute of Metrology reported on studies of tubes using Cd^{114}. Its advantages are: the best continuity when transferring from the present meter to the light-standard meter; presence in the Cd^{114} spectrum of four strong radiations over the visible range which are very useful for the study of a whole order of interferences; the considerably smaller effect of the argon pressure than in the Hg^{198} tube. Studies were carried out on Pb^{206} radiation in particular to 0.5005 μ line; these lines, however, did not prove any better than the radiation already studied by the Advisory Committee.

VNIIM constructed several devices for lengths up to 1 m for direct measurement in wavelengths of either the archive or the engraved standards, for an interference comparison of the archive-type standard with the engraved standards, and for a comparison of the archive-type standard with the engraved standard.

The metrologists of VNIIM feel as a result of their studies that the Cd^{114} tube should be considered as a basic radiation source.

The Central Control Institute of Weights and Measures (Japan) presented a report on wavelength measurements of Hg^{198} and Kr^{86} radiations and also on the determination of the spectrum profile of these lines by three different methods. These studies showed that the Kr^{86} lines have a profile corresponding to the Gauss curve, obtained from the Doppler effect, whereas the shape of the Hg^{198} line diverges from the theoretical Doppler form.

This laboratory also developed an interference comparator for calibrating wavelength scales.

In conclusion the Institute recommended the choice of the Kr^{86} radiation as a standard radiation.

The National Scientific Research Council of Canada presented several reports: on the accurate measurement of the wavelengths of Kr^{86} and Hg^{198} lines in comparison to the red line of cadmium; on the prevention of the reversal of lines in Hg^{198} tubes and on the feasibility of an interference comparator.

The National Bureau of Standards (Australia) reported on several preliminary measurements of Kr^{86} and Hg^{198} radiations. Admitting that the orange radiation of Kr^{86} may be now considered as the best, the laboratory supposes that a choice of standard radiation should be postponed.

Prof. Terrien gave the report of the International Bureau of Weights and Measures. Their studies took two principal directions:

a) a more accurate measurement of wavelengths and of their variations;

b) determination of the line profile by two methods: by means of the Fabry-Perot Standard and the method of line visibility using the Michelson interferometer.

The reason for certain systematic errors appearing in the wavelength measurements presented to the International Committee in 1956 was explained and eliminated.

First of all the effect of the conditions of the tube used was studied: the temperature of the water circulating around the Hg^{198} tube, the power and frequency of the excitation field, temperature and pressure in the Kr^{86} tube, temperature of the Cd^{114} tube.

The equipment is to be further improved, thus increasing the accuracy to better than 10^{-9}.

Judging from the shape of the lines the following basic conclusions were drawn:

1. The width of the line. The measured width of the lines, obtained under optimum conditions, makes possible a merit classification analogous to the order predicted by the theoretical Doppler effect, that is: Kr^{86} radiations are narrower than the Hg^{198} radiations which in turn are narrower than the Cd^{114} radiations. As a result of this, special attention was given to the two elements posessing the narrowest lines.

2. Symmetry. In the best radiation of Hg^{198} (green radiation) the top of the line is asymmetrical when the cooling water is maintained at 20°C; this asymmetry disappears at 4°C and below, but deformations remain which can be explained by the hyperfine structure due to the Hg^{199} isotope, here present to an amount of 1.5%.

In the case of the best Kr^{86} lines, the symmetry is complete with an accuracy of measurement of approximately 0.01 of the width.

Accurate comparisons of the wavelengths with two path differences in the Michelson interferometer give the same relationships for the Kr^{86} lines, which confirms their symmetry whereas this relationship changes with path differences for Hg^{198}, due to the presence of the Hg^{199} isotope and its hyperfine structure.

3. Difficulties. It was found that the best lines of Kr^{86} are less easily disturbed than the best lines of Hg^{198}. It was also recently proved by means of a simple visual observation that visibility is improved (apparently due to the decrease of difficulties) when the krypton tube is cooled in liquid air (58-60°K) instead of liquid nitrogen (63°K).

As all three properties (line width, symmetry and few difficulties) all favor Kr^{86}, the International Bureau considers that the orange radiation $2p_{10}$-$5d_5$ of this mononuclide is from all points of view the best standard of length of any now known.

The laboratories of the International Bureau of Weights and Measures carried out an experiment comparing the two radiation sources for the Advisory Committee. The Fabry-Perot standard, set at 0.5m, was adjusted to obtain a system of rings; by means of a simple rotation of a mirror it was possible to change consecutively from

observation in the orange light of Kr^{86} (Engelgard tube) to observation in green light Hg^{198} (Meggers tube). The rings, completely visible with Kr^{86}, became difficult to distinguish with Hg^{198}.

After the representative of the National Bureau of Standards, Gardner, noted that the Hg^{198} tube used for this experiment contained 1.5% of the isotope of Hg^{199}, whereas it is now possible to obtain Hg^{198} containing 0.2% Hg^{199}, it remained to be seen whether or not the hope of improving monochromatic radiations was justified, if they are to be produced by an atomic-beam tube. Three questions were studied: should one assume that the atomic beam technique will be capable of displacing Kr^{86} from its present position in first place; how long will it take to develop a new lamp; will whatever advantages this atomic beam lamp posesses be counterbalanced by a complicated and expensive apparatus which might limit the use of this lamp to only a few laboratories.

There was no answer to any one of these questions which might lead the Advisory Committee to expect a new decision, especially as the principal considerations lead to the conclusion that the conditions present when radiations are produced in an atomic-beam tube are not particularly favorable for an absolute standard of length.

Having the opportunity of choosing at this time a radiation guaranteeing an accuracy of 10^{-9}, which permits a much more accurate determination of the meter than does the platinum-iridium prototype, the Advisory Committee decided on the following recommendations to the International Bureau of Weights and Measures:

"The Advisory Committee on the Determination of the Meter, having heard the report of the director of the International Bureau of Weights and Measures, confirms the fact that the international platinum-iridium prototype no longer conforms to the demands of precision metrology, and having studied carefully the reports of the large laboratories and of the International Bureau concerning the metrological properties of the now-available radiations, it declares that it is well enough informed to make a recommendation similar to Proposition II which it had adopted in 1953.

"Consequently the Advisory Committee on the Determination of the Meter recommends that the meter be determined by means of radiation corresponding to the transition between levels $2p_{10}$ and $5d_5$ of the atom of krypton^{86}.

"It feels on the basis of corresponding results obtained according to the rules of Proposition III adopted in 1953 that the meter must be determined as equal, as agreed, to 1650763.73 wavelengths of this radiation in a vacuum."

This recommendation will be considered at the regular session of the International Committee on Weights and Measures in October 1958 and at the Eleventh General Conference on Weights and Measures in 1960 which in accordance with the provisions made by the Tenth General Conference held in 1954 should make a decision on the new determination of the meter.

ALL-STATE COMMERCIAL EXHIBITION 1958

"STANDARDIZATION, METROLOGY, STANDARDS AND ACCURATE MEASUREMENTS" HALL

P. P. Arapov

The Committee on Standards, Measures and Measuring Apparatus organized an exhibit of its work in Hall No. 5 of the Machine Construction Pavilion at the All-State Commercial Exhibition which opened in Moscow, May 31, 1958.

In contrast to other years (see "Izmeritel'naia Tekhnika" No. 3 and 4, 1956 and No. 3, 1957) when there were no exhibits on standardization, in 1958 a considerable amount of attention was given to this field.

At the new stand, "Government standardization in the national economy of the USSR" the importance of government standardization and the technical economic effectiveness of individual standards were demonstrated.

In the Soviet Union the great majority of assembly line and mass production is carried out using government standards. Standardized production reaches 90% of the coal industry, 85% of the metallurgical industry, 74% of the oil industry, 80% of forestry and 85% of the machine-tool industry.

On an illuminated panel showing characteristic objectives of the leading branches of the national economy, data were given indicating the increase in production and the decrease in the expenditures for fuel and material due to the introduction of government standards.

In the "Mass Measurement" section the VNII Committee on Standards, Weights and Measuring Devices (VNIIK) demonstrated a class III weight having a mass of 500 kg and an error of ±10 g which it had developed for the checking and control of heavy-load scales. The cast-iron weight is in the shape of a cylinder 425 mm in diameter, inside of which is a steel tube closed on both ends by lids. The interior portion of the tube is used for rectification and the bracket ends serve as a collar for holding the weight. The use of such weights cuts the time taken to check scales by a factor of 2-3.

The same institute produced a set of 0.1 to 5 mg weights for checking and calibrating torsion microbalances and for ultramicroanalysis. The error in the weights does not exceed ±0.0002 and ±0.002 mg respectively.

The Novosibirsk State Institute of Weights and Measuring Devices (NGIMIP) has developed miniature scales for checking technical class III weights and of standard weights with a nominal mass from 1 g to 2 kg. The balances are equipped with a self regulating arm having two arm ratios: 1:1 and 1:5. The largest loads are 200 g and 2 kg and the errors due to arm inequality are no greater than 50 and 400 mg respectively.

In the "Linear Measurements" section single engraved standards of variations in heights for checking profilographs and double microscopes are shown; these have been developed by the VNIIK. These standards are steel plates on whose finished surface V-shaped graduated lines are engraved corresponding to definite classes of regularity of the surface. There are 8 plates in the series.

In the "Pressure Measurements" section the All-State D. I. Mendeleev Scientific-Research Institute of Metrology (VNIIM) demonstrated a sample compensation micromanometer of the second order with a measurement range from 0 to 250 mm water column for checking laboratory micromanometers. The device has two communicating vessels, one of which is stationary and the other can be moved in a vertical direction by means of a micrometer screw. Difference in the levels of liquids in the vessels, as measured on the optical scale of the apparatus, determines the pressure being measured. The error in the measurement does not exceed ±0.04 at the higher limit and ±0.01 mm water column at the lower limit.

The same institute developed and demonstrated at the "Force Measurement" section a sample apparatus for calibrating (by means of a diamond cone) standard samples of 1st degree hardness. The force is produced on the working cone by direct loading, and the load is applied automatically by means of a hydraulic feed.

The Leningrad experimental factory "Standard" showed a tachometric device TKh-4 for the checking of tachometers and tachometric apparatus in the 40-40,000 rpm range. Reproducibility of the angular speeds has an error of not more than ±0.1% of the speed measured. The device is fed by a three phase current network of 220 v, 50 cycles, the power required is 2 kw.

In the "Radiation Measurement" section a sample whiteness comparator, developed by VNIIM is demonstrated for the objective measurement of low-color differences in the white region and for the checking of working scales for whiteness in commercial type comparators. The device consists of two identical systems symmetrically placed on a photometric stand, each of the systems containing a light source and a photoelectric installation. One of the systems is the measuring system and the other is for stabilization.

In the "Temperature Measurement" section NGIMIP demonstrated a cryostat for −60°C using liquid carbon dioxide continuously fed to the chamber through a capillary tube as a cooling agent.

The "Measurement of Time and Frequency" section was supplemented with exhibits developed by the All-State Scientific Research Institute of Physical and Radiotechnical Measurements (VNIIFTRI).

A phasometric installation for the measurement of highly stable frequencies using frequency standards is based on the method of a consecutive relative measurement of phases between the fundamental and multiple

frequencies of these oscillations. The device consists of a standard oscillograph tube (8LO39) with corresponding power sources of the scanning unit by means of which circular scanning is formed on the tube screen from standard frequencies of 1-10-100 kc and from the pulsing unit which gives pulses at the highly stable frequencies 1-10-100 kc. The device measures only very close frequencies with an error of $1 \cdot 10^{-11}$.

Quartz resonators, developed by VNIIFTRI for frequencies of 500 and 1600 kc are used in frequency and time standards in quartz generators and in frequency-measuring devices. Specially treated quartz is used as an oscillating element in the resonators.

In the "Electrical Measurements" section a portable three-phase device, developed by the Gorki GKL, was shown. The equipment is carried in a specially equipped GAZ-69 automobile and is quickly and easily unpacked and set up. It operates on a 380 and 220 v network.

In the thermowattmeter, developed by the VNIIM, errors brought about by the unstable volt-ampere properties of the thermoconverters have been eliminated so that the accuracy of the instrument will be maintained when the readings change. The apparatus can measure power both with high and low power factors over a frequency range of 50-10,000 cycles with an error of not more than ±1%. The limits in the current measurement are 0.2, 0.5, 1, 2.5 and 10 amp, and in voltage, 20, 50, 100 and 200 v.

The VNIIM high-accuracy ammeter consists of two units, a thermoattachment and a direct-current ammeter. The apparatus is designed for the measurement of current in direct and alternating current networks over the frequency range from 50-10,000 cycles with a maximum error of not more than ±1%. The measurement limits are 0.05, 0.1, 0.25, 1, 2.5, 5 and 10 a.

Two VNIIM exhibits were shown in the "Radiotechnical Measurements" section. They were:

UINI-2 for checking devices which measure the coefficient of nonlinear distortions, operating over the range of audio frequencies from 60-20,000 cycles and measuring the coefficient of nonlinear distortions over the limits of 0.3 to 50% with a 1-v input signal and with an output impedance of 10-220 kohms. A diode peak compensation voltmeter is used as a frequency indicator from 60 to 300,000 cycles. The maximum error in the UNINI-2 is 1%.

UGSS-2 for checking standard signal generators for the output voltage or power over a frequency range from 20,000 to 700,000 cycles including the sample compensation diode voltmeter of the OKV-2 type, a low-power meter of the IMM-2 type and a metering receiver of the IP-1 type.

Apparatus developed by VNIIFTRI was exhibited in the same section.

Standard equipment for checking GSS in a pulsed modulation system makes it possible to carry out measurements of the temporary parameters of radio pulses of 0.1 to 250 μsec duration having an amplitude from 0.1 to 1 v with an error of ± 5 to 20% in the measurement of the fronts and ±5% +0.02 μsec when measuring time; temporary parameters of 0.1 to 250-μsec video pulses having an amplitude from 0.02 to 0.2 v with an error of ±5% +0.02 μsec; asymmetry of square radio pulses with a half-period ratio of 1:1 and an amplitude from 0.1 to 1 v with an error of 5%; radio pulse frequencies over a range from 100 to 10,000 cycles with an error of ±3% and of retardation times for output radio and video pulses over a range of from 1-500 μsec with an error of ±10%.

The TA-1 standard milliammeter for testing and checking thermomilliammeters up to 30 ma is based on the principle of substituting a direct current (which can be measured by an accurate milliammeter) for the high-frequency current which goes through a thermotransformer. The range of measurements is from 1-30 ma, frequency range up to 100,000 cycles, error ±1%.

Standard ammeter OFA-2 is designed for testing and checking of thermoammeters. The range of measurements is from 30 ma to 5 amp, frequency range up to 100,000 cycles, with an error in current measurements up to 1 amp and 100,000 cycles frequencies of not more than ±0.7% and for currents above 1 amp, with frequencies of 30,000 and 100,000 cycles of not more than ±1% and ±2% respectively.

A standard ammeter EDA-3 is designed for testing and checking of thermoammeters. The range of measurements is from 5 to 20 amp, the frequency range from 1000 to 100,000 cycles with an error of ±1%.

A phasometric apparatus for measuring high stability frequencies using standard frequencies with an error of $\pm 1 \cdot 10^{-11}$.

SETTING UP MEASUREMENTS CONTROL UNDER CONDITIONS OF INDUSTRIAL MANAGEMENT REORGANIZATION

V. N. Solov'ev

As the result of the industrial and construction management reorganization, the State Inspection Laboratories for Measuring Equipment (SIL) of the Committee for Standards, Measures and Measuring Instruments have obtained the opportunity of actively controlling the condition of measuring equipment and inspecting it, not only directly in the industrial establishments but also through the Councils of National Economy. The Ivanovo SIL established close business contact with the CNE of the Ivanovo Economic Region Administration from the very first days of its formation.

In the first place we insisted on measures for preserving the existing instrument repair organizations, administrative inspection agencies in industrial establishments and base laboratories of the abolished ministries and administrations. As early as June 1957 we presented to the Council of National Economy appropriate proposals in this connection, as well as suggestions for determining the extent and volume of their work and the establishment by the Council of National Economy within its framework of such organizations, and the transfer of existing organizations into that framework.

Secondly, in conjunction with the Sovnarkhoz (Soviet Narodnogo Khozyaistva – Council of National Economy) we worked out a system for inspecting measures and measuring instruments. Instructions for the inspection of measures and measuring instruments within the framework of the Council of National Economy were prepared as well as regulations for base laboratories and their relations with establishments. These documents were approved by the Sovnarkhoz Chairman and came into force in November 1957. At the same time the setting-up of three base laboratories for inspection, repair and adjustment was provided for. One of the laboratories was set up at the "Promėnergo" office and the other two in the instrument-making plants "Ivmashpribor" and "ZIP."

The inspection instructions were worked out on the basis of the standard "Instructions for the Administrative Inspection of Measures and Measuring Instruments" recommended by the former Committee for the Affairs of Measures and Measuring Instruments, taking into consideration the changes which have taken place in the administrative structure of industry and the form of state control of measures and measuring instruments. In particular, the instructions ensure the right of the establishment and agency managers themselves to establish the dates for checking most of the measures and measuring instruments, providing the managers can guarantee their continuous efficiency and accuracy. They are also empowered to use, for this checking, the personnel of their establishments and base laboratories in agreement with the SIL. The instruction also obliges the heads of the administrative inspection departments to instil new measuring techniques in industry, to observe the operational and design qualities of new instruments and to study and draw conclusions from these observations and also to develop and instil the practice of controlling, by means of instruments, the quality of production at all the stages of manufacture. The instruction notes that the SIL not only controls the condition of measuring equipment but enforces state standards and manufacturing specifications. The heads of the Sovnarkhoz establishments and agencies are requested to render the SILs every assistance for carrying out the work outlines above.

The supervision of administrative inspection is entrusted by the Council of National Economy to the Chief Mechanical and Power Engineer's Departments where these functions are exercised by one of the responsible members of the department. In the Sovnarkhoz industrial administrations, supervision is entrusted to the Chief Mechanical Engineer's Department or to the Engineering Department. Here, responsibility is also delegated to one of the engineers of the department. At establishments and agencies, supervision will be exercised by heads of the inspection departments or persons responsible for the measuring equipment and appointed by the establishment managers from among the engineers in the Chief Mechanical or Power Engineer's Departments or the Technical Inspection Department.

As stated above three laboratories were set up within the Sovnarkhoz framework: one in the offices of "Promėnergo" for electrical and thermal instruments, another at the "Ivmashpribor" plant for instruments used in the textile industry, and the third at the "ZIP" plant for instruments testing mechanical properties of metals.

The "Proménergo" base laboratory has been fully equipped and commenced functioning from the fourth quarter of 1957. The equipment of the other two laboratories is being completed.

The base laboratories operate according to instructions approved by the Sovnarkhoz on the basis of mutually agreed contracts with establishments.

The "Proménergo" laboratory, for instance, has concluded, by the beginning of this year, 80 contracts with its customers and now it regularly checks their electrical and thermal instruments according to specifications and in the time agreed upon between them, carries out routing inspection and repairs when required, assembles and installs new instruments, renders technical assistance in selecting the means and methods of measuring and in designing circuits and graphs for checking instruments, and provides instruction to persons responsible for the measuring equipment and to those using it.

The regulation provides the Laboratory, as a Sovnarkhoz Department, with the right to issue to the establishments within its own sphere binding instructions for removing defects in condition of the measuring equipment or in the methods of measuring. All the work is mainly carried out at the establishments. If necessary, some instruments are sent to the laboratory for checking or repair.

The "Proménergo" laboratory checks and repairs a wide range of instruments, possessing for this purpose the required premises and a large variety of portable and stationary measuring equipment and standard instruments. The laboratory personnel consists of 40 people including 15 engineers and technicians. The Laboratory is a highly specialized department for the inspection of measures and measuring instruments within the Sovnarkhoz framework and is capable of carrying out work at a high technical level.

The work of other base laboratories is organized on a similar basis.

In addition to this laboratory the region has an instrument repair factory, which as well as repairs, exercises technical supervision over the instruments for mass mechanical measurements in all the branches of the regional economy.

The measures adopted by the Sovnarkhoz regarding inspection of measures and measuring instruments have produced positive results but they cannot be considered as complete or adequate. This year it is necessary to organize a base laboratory and repair and adjusting shop for length and angle measuring instruments and to ensure efficient supervision of the administrative inspection agencies at the establishments and base laboratories.

In the second half of 1957 the work of our laboratory was affected by the instructions of the Committee on the experimental modification of the laboratory's state inspection of measures and measuring instruments. The modification consisted of granting the heads of establishments and agencies greater rights in managing the measuring equipment of their establishments and increasing their responsibility for the maintenance of the measuring equipment. They can fix, of their own accord, the dates for the inspection of the greater part of measures and measuring equipment, depending on their type and conditions of operation. The inspection can be carried out by the personnel of the establishments and agencies possessing this equipment. If they lack the means for doing it the equipment can be checked in the laboratories of the Committee or administrative inspection laboratories which have the right to inspect equipment.

The criterion of proper maintenance of measuring equipment in establishments and agencies is their constant efficiency and accuracy and their correct use.

In this connection our inspection work has also radically changed.

Mass inspection, which previously amounted mainly to checking the validity of stamps on the instruments, is now replaced by actual testing of the measures and measuring instruments and rendering every assistance to the establishments in measuring-equipment problems.

The new methods of State inspection were reported to the Council of National Economy.

The SIL introduced the new methods of state control of measures and measuring instruments in four towns and districts of the region. In this area there are 46 Sovnarkhoz establishments. In six months the number of inspection agencies doubled in these establishments and by the first of January 1958, in conjunction with the base laboratories, they extended their control over 81% of the measures and measuring instruments. At the beginning

of this period inspection of the establishments revealed that 6.8% of the instruments were inaccurate, out-of-order or with outdated calibrations. By the end of the period, however, their number decreased to 2%, moreover, there were no inaccurate instruments found in actual checking.

The joint effort of the SIL and the Sovnarkhoz also led to the setting up of administrative inspection agencies at other establishments and to the improvement of the condition of the measuring equipment.

The SIL intends in future to introduce measures in conjunction with the Sovnarkhoz for improving the measuring equipment of the region. Among these measures should be mentioned the exchange of experience among the inspection workers, the establishment of new and the enlargement and strengthening of existing inspection agencies, improvement of inspection workers' qualifications, etc.

Similar measures are planned for local establishments and industrial organizations.

EXPERIENCE GAINED IN THE STALINO STATE MEASURING-EQUIPMENT INSPECTION LABORATORY

E. F. Garazha

The Stalino State Measuring-Equipment Inspection Laboratory controls a large assortment of modern measuring instruments in the largest metallurgical, engineering, chemical and other Donbas enterprises.

The Laboratory staff work in close collaboration with the regional, city and district Party and Soviet organizations.

Any defects discovered in the condition of the measuring equipment, any infringements of standards or technical specifications we always report to the Party Regional Committee and the Regional Soviet E.C.* and to the Corresponding Party District Committees and District Soviet E.C.'s. Our workers often write articles in the local press criticizing those responsible for an unsatisfactory condition of the measuring equipment or the infringement of standards.

Contact with the Soviet and Party organizations and the press provide a speedier correction of defects with a smaller effort.

On our initiative the production of portable automobile scales was organized at the "Vtorchermet" Konstantinovka plant and the production of stationary motor-van mounted scales at the "Vesotochmash" plant (Zhdanov city). The Stalino Regional Soviet E.C. decided to install automobile scales in every collective farm.

We became alarmed at the unsatisfactory condition of the weighing equipment repair shops run by the Regional Local Industry Agency. We photographed all the repair shops and compiled and submitted a report to the Party Regional Committee and the Regional Soviet E.C. Reporting the matter to Party and Soviet organizations and writing about it in the press helped to improve the work of the shops. At a conference of the heads and foremen of weighing equipment repair shops and workers of the State Inspection Laboratory, measures were worked out for improving the conditions of the shops. The Regional Soviet E.C. allocated the necessary sums and workshop premises were renovated in Konstantinovka, Artemovsk, and Enakievo and new premises provided in Kramatorsk, Zhdanov and other towns.

As the result of our inspection of measuring instruments in hospitals and druggist shops, the Regional Health Department issued an instruction on the organization of the repair of all the measuring instruments and on the organization of their technical supervision which would ensure their constant working efficiency.

The method of running provisional branches in the districts has also changed. The head of a provisional branch now works in close collaboration not only with the district Party and Soviet organizations but also with settlement and village Soviets. As a rule local organizations render active assistance in the running of the branches.

*Economic Council.

Workers of provisional branches of E. M. Khomov, Iu. P. Tarash, G. I. Grimkovskii, L. D. Maridzon, A. P. Barannik and others take part in district meetings of active workers, write to the district press, speak at conferences called by the Party District Committees and District Soviet E.C.s, reporting on the importance measuring instruments, methods of using them, etc.

It should be noted that it was with the assistance of the Regional Committee of the CPSU and the Regional Soviet E.C. that premises were obtained for the State Inspection Laboratory and its departments. For the Stalino State Inspection Laboratory a special building was constructed; in Kramatorsk, premises with a floor space of 160 m^2 and in Zhdanov, premises with a floor space of 80 m^2 were allocated.

It is quite clear that the State Measuring Equipment Inspection Laboratory will work better and its influence on the condition of the measuring equipment will be more effective and secure if it relies in its day-to-day activity on the assistance of Party and Soviet organizations and the press.

From the Editorial Board. E. F. Garazha deals with an interesting question of great importance for the work of State Measuring Equipment Inspection Laboratories and of their departments. The Editorial Board invites readers to comment on E. F. Garazha's article and to send in accounts of their own experiences.

INSPECTION WORK OF CENTRAL MEASURING LABORATORIES IN ENGINEERING PLANTS

V. G. Shtein

Since 1957 the All-Union Technical Design Institute (AUTDI) of the USSR State Planning Committee began introducing, on the present author's suggestion, in all Central Measuring Laboratories and Inspection Control Points of heavy-engineering plants a number of measures designed to strengthen the role of the Central Measuring Laboratories, as the main organizing center for measuring equipment at the plant, by simplifying the pure inspection work of the laboratories.

Such measures include calibration recording without certificates, decreasing the number of scale check points in calibration and the handing-over of checking the simplest instruments to the workers who use them.

Calibration recording without certificates. Unified registration forms and cancellation of permanent rating records and certificates for measures and measuring instruments was granted by the Committee for Standards, Measures and Measuring Instruments' instruction (No. 20) of January 14, 1957, providing the enterprise ensures a strict control over the specified dates for checking the calibration of measures and measuring instruments and records the fact by marking them with a conventional sign.

With this inspection method certificates are only issued for measures and instruments which require error corrections in their operation (plane-parallel thickness gauges, angle gauges and screw-thread gauges). All the remaining certificates are cancelled.

All inspection (obligatory and periodic) is conducted according to the periodic-inspection charts, where the dates of inspection and the number of each tool or instrument are listed; the forms for the periodic-inspection charts and the methods of their application were published in the journal "Measurement Techniques" (No. 6, 1956).

Approved measuring instruments are stamped by the Central Measuring Laboratory or the Inspection Control Point inspector with a rubber stamp with adjustable dates set for the next inspection time (the period of the instrument validity).

The following stamping composition is recommended: ethanol colorless lacquer (TU MKhP 3677-44) with added pigments which can be made of Mars red (TU MKhP 1087-44) or carbon-black, and for stamping black

surfaces of zinc white. The composition should consist of 90% lacquer and 10% pigment. Good results are obtained from: 39% iditol (synthetic resin according to GOST 2230-43), 60% redistilled alcohol, 1% orange sudan dye.

The stamp produced by above composition is durable and cannot be removed by petrol, oil or emulsion. In routine checking it can be easily removed by an acetone solvent No. 646 or RDV and the ethanol lacquer by turpentine.

Stamps for slide gauges and other tools are made of a saturated solution of copper sulfate – 1 liter, nitric acid with a 1.4 specific gravity – 0.1 liter, a 10% solution of potassium bichromate – 0.2 liter, and water – 0.1 liter, which need not be added if the stamp is pale. This stamp cannot be rubbed out or removed by solvents. Slide gauges are checked periodically every 3 to 6 months and in case of approval the stamp can be covered over by the same composition and new stamp affixed next to it; after repairs the stamps can be easily removed by the mechanic with a fine emery cloth.

The annotation of the measuring-instrument's calibration data and of its condition (valid, for repair, or for scrap) and the stamp of the date of checking on the instrument itself (paraffining for gauges) makes rating records and certificates superfluous.

In the rubber stamp the date is marked only by the year and month and the remaining figures are used as a code for the shop and the inspector's number. Obligatory checking is denoted by a zero before the date. In obligatory calibration the date of the following periodic checking is stamped on.

In State calibration the validity (year of calibration) is stamped on by a rubber stamp approved by the Committee for Measures and Measuring Instruments.

When sending an item away for repair the inspector does not make out a repair card. He simply erases from the instrument the part of the stamp showing the year and month of calibrations, leaving the figures (code of the shop) and passes the instrument to the repair shop. From the repair shop the instrument is returned to the tool-room against a signature in a logbook.

If an instrument is condemned, it is made unusable without filling any rejection forms. Such an instrument is written off in the usual manner.

Thus, the Inspection Control Point inspector does not make any entries or fill any certificates under any conditions of workshop calibration.

Above routine has been adopted in the Central Inspection Laboratories and Inspection Control Points of a diesel plant.

Establishing a minimum number of check points for daily and periodic tests. Recently a reduction of the number of elements and points to be checked in daily and periodic tests as compared with those established by the Committee's instructions has been allowed. The question of which elements and points should be checked is left to the enterprises themselves to decide according to the amount of use of the measures and instruments, the conditions of the application and the importance of the measurements carried out with them. The obligatory calibration is carried out on all elements and points listed in the Committee's instruction.

The All-Union Technical Design Institute of the USSR State Planning Committee has accordingly issued a general instruction on methods of checking according to its form: whether it is daily or periodic.

In end-of-shift checks (when handed in from the benches) universal measuring instruments are visually examined, checked for completeness and operation of the mechanism, and always checked in the zero or lowest measuring position by means of reference gauges but without using plane-parallel thickness gauges.

In gauges one dimension is checked by means of counter-gauges or universal measuring instruments.

Measures and optical and mechanical measuring instruments are not checked after every shift.

No marks are made denoting checking or approval of instruments (except paraffining).

Periodic tests are carried out on all measures, gauges, universal measuring instruments (excepting slide gauges with divisions of 0.1 mm and a length up to 200 mm) and optical instruments in use at the plant.

In periodic testing, external inspection is carried out, the instrument is checked for missing parts and correct operation according to instructions of the Committee.

Checking of sizes is carried out in an abridged manner. The elements to be checked and the check points for each type of a universal measuring tool or optical instrument are given in the All-Union Technical Design Institute instructions mentioned above.

Compulsory checking after repairs is extended not only to universal measuring tools and instruments which have undergone overhauls or important repairs, but also to tools after current repairs or readjusted instruments which are checked for the elements and at points specified for periodic testing.

Simple testing of measuring devices by the workers themselves. This is one of the measures for improving and simplifying inspection which raises the general level of skill in handling measuring devices in the shops. Thus, at the "Kalibr" diesel plant, the Kolomna locomotive plant, and others, the slide gauges with 0.1 mm divisions and a range up to 200 mm are checked by inspectors only when returned from the shop in order to guarantee the accuracy of the instrument when it is re-issued again; it is not included in the periodic inspection chart and for the whole period of its use in the shop the responsibility for its accuracy rests with the worker himself.

One of the preliminary steps for transferring the calibration to the workers themselves is the installation in some of the shops of test benches with sets of reference gauges and plane-parallel thickness gauges to enable the workers to check the accuracy of their measuring tools at any time.

At one of the conferences of the heads of Central Inspection Laboratories in Gor'kii in 1957 it was suggested that such measures should be accompanied by new methods of work in keeping the uniformity of measurements in the plant, so that the workers would themselves feel the necessity of preserving the efficiency of the measuring tools they are using and become interested in their accuracy.

Such measures include, in the first place, an improved skill in using the measuring tools. For this purpose the Inspection and Control Point inspectors should regularly, at least twice a month, make the round of shops and instruct the workers in the correct handling of measuring devices: their storing on the bench, correct use, checking of the zero position and zero adjustments in slide gauges and micrometers, timely submission of measuring devices for checking according to the date stamped on them, etc; the inspectors should accompany explanations by actual checking of the accuracy.

It is not enough to make the round of benches, observing how the measuring tools are being used; the inspectors should organize the foremen and workers in preparation for them to take care themselves of the accuracy of measuring devices they are using, assigning tools to workers for long periods and instruments according to their degree of accuracy to definite groups of workers.

Workers should be made responsible for the scrap due to wrong or careless use of measuring devices (for instance a micrometer with a wrongly set zero).

Conclusions. All these measures will simplify the work of the Central Inspection Laboratories and Inspection and Control Points in checking measures, measuring tools and instruments, will raise the skill in their use and will enable these agencies to devote their efforts to the introduction of the latest measuring technique in the control points and in the shops.

Side by side with these measures it is advisable under favorable conditions to raise the question of the amalgamation of the Central Measuring Laboratories with other laboratories (such as thermal and electrical) in order that such unified laboratories should examine jointly the questions of introducing new measuring technique into the shops.

ANALYSIS OF THE RESULTS OF CHECKING GAUGES AND INSTRUMENTS

E. F. Dolinskii

A bad organization of production leads to scrap. This statement is fully applicable to the checking of gauges and instruments. Scrap in this instance will consist of incorrectly calibrated gauges or instruments. This article suggests a technique for evaluating this scrap and a choice of conditions for practically eliminating it or reducing it to tolerable dimensions.

The general problem of analyzing results of checking gauges and instruments can be divided according to the number of check "points" and the type of prevailing errors into the following categories;

a) checking constant-value gauges;

b) checking sets of gauges and instruments with constant systematic errors only;

c) checking instruments with random errors only;

d) checking instruments with systematic and random errors, which is the general case.

Checking constant value gauges. The problem of selecting measuring devices, akin to the one studied here, was first precisely formulated by N. A. Borodachev [1]. Following his technique let us divide the gauges subject to testing into four categories: a) actually satisfactory and passed as such W_{11}%; b) unsatisfactory and condemned W_{21}%; c) unsatisfactory but passed as satisfactory W_{31}%; d) actually satisfactory, but condemned W_{41}%.

Let us introduce the notation:

$\varrho(x)$ and $\varphi(y)$ are the probable distribution densities of systematic constant errors for the aggregate of the tested and reference gauges respectively,

Δ_x is the permissible error of the tested gauge.

Then the percentage content of gauges whose errors lie in the limits ($-\Delta_x$ and Δ_x) and which have been passed as satisfactory will amount to:*

$$W_{11}=2\int_0^{\Delta_x}\varrho(x)\left[\int_{-(\Delta_x+x)}^{\Delta_x-x}\varphi(y)\,dy\right]dx. \tag{1}$$

Further,

$$W_{21}=2\int_{\Delta_x}^{\infty}\varrho(x)\left[\int_{-\infty}^{-(\Delta_x+x)}\varphi(y)dy+\int_{(\Delta_x-x)}^{\infty}\varphi(y)\,dy\right]dx, \tag{2}$$

$$W_{31}=2\int_{\Delta_x}^{\infty}\varrho(x)\left[\int_{-(\Delta_x+x)}^{\Delta_x-x}\varphi(y)\,dy\right]dx, \tag{3}$$

$$W_{41}=2\int_0^{\Delta_x}\varrho(x)\left[\int_{-\infty}^{-(\Delta_x+x)}\varphi(y)dy+\int_{(\Delta_x-x)}^{\infty}\varphi(y)\,dy\right]dx. \tag{4}$$

The checking scrap will consist of the third and fourth category checked gauges. Their total will be

$$WB_1=W_{31}+W_{41}. \tag{5}$$

The gauges of the first and third groups, passed as satisfactory, will remain in circulation, but the second and fourth groups will be withdrawn.

*For the sake of simplicity the calculations have been limited by symmetrical distribution laws; if the error of the method of comparison must be taken into consideration, $\varphi(y)$ should be replaced by $\varphi(y+\xi)$, where ξ represents the error of the method.

Later the aggregate consisting of the first and third groups will be subjected to the next, second, periodic checking. After the second checking there will remain in circulation only groups W_{12} and W_{32}

$$W_{12}=2\int_0^{\Delta_x}\varrho(x)\left[\int_{-(\Delta_x+x)}^{\Delta_x-x}\varphi(y)\,dy\right]^2 dx. \tag{6}$$

$$W_{32}=2\int_{\Delta_x}^{\infty}\varrho(x)\left[\int_{-(\Delta_x+x)}^{\Delta_x-x}\varphi(y)\,dy\right]^2 dx. \tag{7}$$

Similarly after the n-th checking there will remain

$$W_{1n}=2\int_0^{\Delta_x}\varrho(x)\left[\int_{-(\Delta_x+x)}^{\Delta_x-x}\varphi(y)\,dy\right]^n dx, \tag{8}$$

$$W_{3n}=2\int_{\Delta_x}^{\infty}\varrho(x)\left[\int_{-(\Delta_x+x)}^{\Delta_x-x}\varphi(y)\,dy\right]^n dx. \tag{9}$$

The checking scrap for n checks will amount to

$$W_{Bn}=2\int_0^{\Delta_x}\varrho(x)\,dx-W_{1n}+W_{3n}. \tag{10}$$

The application of (10) requires the knowledge of functions $\varrho(x)$ and $\varphi(y)$. The distribution of errors of the checked gauges depends on the method of their manufacture and the number of previous checks. In the case of reference gauges it is necessary to take into account the errors of manufacture and the scrap due to calibration by means of other gauges of a higher order of accuracy; for the latter their errors of manufacture and the scrap due to calibration by gauges of a still higher order should be taken into account, etc. Hence, the analysis of checking a given accuracy reference gauge requires the previous evaluation of the checking scrap of all the higher-accuracy gauges, since only thus can function $\varphi(y)$ be evaluated.

As a numerical example a system with three categories of gauges is given below.

For gauges of the 1st category, which are checked by sufficiently accurate methods, it is possible to assume a truncated normal distribution within the limits determined by the permissible error which we shall denote by Δ_z.

The error of gauges of the 2nd category, checked by means of gauges of the first category m times will have an error distribution density of the form:

$$\varphi_m(y)=\frac{1}{2\int_0^{\infty}\varphi(y)\left[\int_{-(\Delta_y+y)}^{\Delta_y-y}f(z)\,dz\right]^m dy}\,\varphi(y)\left[\int_{-(\Delta_y+y)}^{\Delta_y-y}f(z)dz\right]^m \tag{11}$$

This distribution is due to errors of manufacture represented by $\varphi(y)$ and also due to the presence among the checked gauges of unsatisfactory gauges W_{3m} and that a part of the satisfactory gauges

$$(W_{41}+W_{42}+\ldots+W_{4m})$$

has been withdrawn.

Similarly the distribution of errors of the 3rd-category gauges, if they have been checked n times, will be

$$\varrho_n(x)=\frac{2}{W_{1n}+W_{3n}}\,\varrho(x)\left[\int_{-(\Delta_x+x)}^{\Delta_x-x}\varphi_m(y)dy\right]^n \tag{12}$$

Formulas (11, 12, and 6 to 10), in conjunction with the assumption about the distribution of errors of the 1st category gauges, provides an evaluation of the scrap in the 2nd and 3rd category gauges.

The results of the corresponding calculations for m = n = 1 and for certain relations between the permissible errors Δ_x, Δ_y and Δ_z and the errors characterizing the quality of their manufacture σ_x, σ_y and σ_z are given in Tables 1 and 2. Quantities σ_x, σ_y and σ_z denote mean square errors of the aggregate of the 3rd-, 2nd- and 1st-category gauges before they have been subjected to any checking. Variables $\underline{x}$ and $\underline{y}$ are assumed to be distributed according to the normal law with their center at zero.

TABLE 1

Results of Checking 2nd Category Gauges

$\frac{\sigma_y}{\sigma_z}$ \ $\frac{\Delta_y}{\sigma_y}$	$\lvert z\rvert < 2\sigma_z$						$\lvert z\rvert < 3\sigma_z$					
	W_{21}%		W_{11}%		$W_{B_1}=(W_{21}+W_{11})$%		W_{21}%		W_{11}%		$W_{B_1}=(W_{21}+W_{11})$%	
	2	3	2	3	2	3	2	3	2	3	2	3
2	1.26	0.09	3.40	0.44	4.66	0.53	1.30	0.09	3.97	0.52	5.27	0.61
3	0.95	0.07	1.86	0.20	2.81	0.27	1.00	0.07	2.17	0.22	3.17	0.29

TABLE 2

Results of Checking 3rd Category Gauges

$\frac{\Delta_y}{\sigma_y}=\frac{\sigma_y}{\sigma_z}=2;\ \lvert z\rvert<2\sigma_z$ $\qquad$ $\frac{\Delta_y}{\sigma_y}=\frac{\sigma_y}{\sigma_z}=3;\ \lvert z\rvert<3\sigma_z$

$\frac{\sigma_x}{\sigma_y}$ \ $\frac{\Delta_x}{\sigma_x}$	W_{21}%		W_{11}%		$W_{B_1}=(W_{21}+W_{11})$%		W_{21}%		W_{11}%		$W_{B_1}=(W_{21}+W_{11})$%	
	2	3	2	3	2	3	2	3	2	3	2	3
2	1.25	0.09	3.31	0.40	4.56	0.49	1.30	0.09	3.96	0.52	5.26	0.61
3	1.00	0.08	1.89	0.19	2.89	0.27	1.05	0.08	2.18	0.23	3.23	0.31

Tables 1 and 2 show that one and the same ratio of permissible errors Δ_x/Δ_y of the checked and the reference gauges corresponds to different values W_B; the converse statement that one and the same W_B can be obtained for different values of Δ_x/Δ_y also holds. In fact

$$\frac{\Delta_x}{\Delta_y}=\frac{\frac{\Delta_x}{\sigma_x}}{\frac{\Delta_y}{\sigma_y}}\cdot\frac{\sigma_x}{\sigma_y}=\frac{K_x}{K_y}\,K_{xy}=K.$$

Therefore, it is possible to obtain one and the same value of K by obtaining different values of K_x, K_y and K_{xy}, at the same time W_B will also assume different values.

Thus from Tables 1 and 2 it follows that:

at $K=3$ a) $\frac{K_x}{K_y}K_{xy}=\frac{3}{3}\cdot 3;$ $\qquad W_B=0{,}3\%;$

b) $\frac{K_x}{K_y}K_{xy}=\frac{3}{2}\cdot 2;$ $\qquad W_B=0{,}5\%;$

c) $\frac{K_x}{K_y}K_{xy}=\frac{2}{2}\cdot 3;$ $W_B=2{,}9\%;$

at $K=2$ a) $\frac{K_x}{K_y}K_{xy}=\frac{3}{3}\cdot 2;$ $W_B=0{,}6\%;$

b) $\frac{K_x}{K_y}K_{xy}=\frac{2}{3}\cdot 3;$ $W_B=3{,}2\%;$

c) $\frac{K_x}{K_y}K_{xy}=\frac{2}{2}\cdot 2;$ $W_B=4{,}6\%.$

These examples point among other things to the fact that a smaller value of K can give a better result than a larger value, as can be seen from comparing case (c) for K = 3 with case (a) for K = 2.

General conclusions from Tables 1 and 2 amount to the following.

1) The probable checking scrap depends on the distribution of errors of the reference and tested gauges and cannot be determined as a single-valued function of the ratio of tested and reference gauge errors.

2) The checking scrap depends mainly on the ratio of Δ_x/σ_x, whose rise leads to a considerable decrease in W_B.

3) The relation of the mean-square manufacturing error of the tested and reference gauges, i.e., σ_x/σ_y has a much smaller effect on W_B than Δ_x/σ_x.

4) The relative number of actually satisfactory but condemned gauges considerably exceeds that of unsatisfactory but approved gauges. Hence, the checking scrap hits mainly the gauge manufacturer.

It is of interest to find out whether it is worth while checking a given gauge on two or more reference gauges of the same type. In order to solve this problem let us denote

$$P_1=\int_{-(\Delta_x+x)}^{(\Delta_x-x)}\varphi(y)dy; \qquad P_2=\int_{-\infty}^{-(\Delta_x+x)}\varphi(y)dy+\int_{\Delta_x-x}^{\infty}\varphi(y)dy.$$

Then the probability of correct classification of gauges after the second checking will be A_1:

$$A_1=2\int_0^{\Delta_x}P_1Q(x)dx+2\int_{\Delta_x}^{\infty}P_2Q(x)dx,$$

checking by means of two gauges we shall obtain

$$A_2=2\int_0^{\Delta_x}P_1^2\,Q(x)dx+2\int_{\Delta_x}^{\infty}(2P_1P_2+P_2^2)Q(x)dx.$$

Whence after certain transformations, remembering that $P_1 + P_2 = 1$, we obtain

$$A_2-A_1=2\left[\int_{\Delta_x}^{\infty}P_1P_2Q(x)\,dx-\int_0^{\Delta_x}P_1PQ(x)\,dx\right]<0^{*}.$$

*For practical values of Δ_x.

Thus checking by means of two or more gauges produces worse results than checking with one gauge. This somewhat paradoxical result is explained by the fact that when checking with two reference gauges the number of gauges which are actually satisfactory but have been rejected increases as the result of comparing them with one or the other of the reference gauges.

The general conclusion arrived at from above reasoning concerning gauges of a constant value is the following. A rational selection of tolerances for reference gauges is determined by the distribution of errors of the tested and reference gauges, the tolerances of the tested gauges and also by technical and economic considerations. The latter must determine the permissible percentage of scrap in checking. The parameters of the aggregate of reference gauges must satisfy the condition determined by (10), i.e.,

$$W_{Bn} = \left[2\int_0^{\Delta_x} \varphi(x)dx - W_{1n} + W_{3n} \right] 100\% < W_{n\ pr}\ \%.$$

where $W_{n\ pr}$ % is the permissible percentage of scrap in checking.

It should be noted that it is impossible to establish any general value for the relation of permissible errors $K = \Delta_x/\Delta_y$. This is confirmed by measuring practice providing values of K which lie mostly in the range of $1.5 \leq K \leq 5$.

Checking sets of gauges. The problem of checking sets of gauges or instruments with negligible random errors differs from the problem just examined only in checking them at several points. The results of checking depend on the indications obtained at each of the points. If a reading is outside the limits at one of the points only the instrument is rejected.

The formulas quoted above hold for each of the check points. Assuming that the errors at each point are independent of each other the checking results can be obtained from the expression

$$\Pi_i = (W'_{11} + W'_{21} + W'_{31} + W'_{41})(W''_{11} + W''_{21} + W''_{31} + W''_{41}) \ldots\ldots (W^i_{11} + W^i_{21} + W^i_{31} + W^i_{41}),$$

where the indices represent the check points.

For the particular case of an even distribution of errors over all the check points this product becomes

$$\Pi_i = (W_{11} + W_{21} + W_{31} + W_{41})^i. \qquad (13)$$

For two points the latter product becomes

$$\Pi_2 = (W_{11} + W_{21} + W_{31} + W_{41})^2.$$

The checking scrap will then be

$$W''_B = W^2_{31} + W^2_{41} + 2W_{11}W_{31} + 2W_{11}W_{41}.$$

By similar reasoning it is possible to find scrap for any number of points. In Tables 3 and 4 checking scrap data for checking in one, two, five and ten points are given; the data were compiled from Table 2 and relation (13).

It is possible for the errors in different points of the same instrument to be functions of a certain parameter, for instance, the value of the measured quantity, instead of being independent of each other. In such a case the checking scrap probability determined from (10) will also be a function of the parameter.

Checking of instruments with random errors only. The object of such checking consists, strictly speaking, in determining the law of distribution of random errors and in finding the numerical parameters, which determine the error distribution curve of the given instrument at each given point.

A complete solution of such a problem involves a large amount of experimental work and calculations. Such a solution is difficult even in testing standard instruments and with ordinary ones it is practically impossible.

TABLE 3

Values of W_B in %; $|z| \leq 2\sigma_z$

σ_x/σ_y \ Δ_x/σ_x	Checking, in 1 point		2 points		5 points		10 points	
	2	3	2	3	2	3	2	3
2	4.6	0.5	8.5	1.0	17.4	2.5	24.6	4.8
3	2.9	0.36	5.4	0.5	11.2	1.3	16.8	2.5

TABLE 4

Values of W_B in %; $|z| \leq 3\sigma_z$

σ_x/σ_y \ Δ_x/σ_x	Checking, in 1 point		2 points		5 points		10 points	
	2	3	2	3	2	3	2	3
2	5.3	0.6	10.3	1.2	21.3	3.2	28.4	6.2
3	3.2	0.3	6.3	0.6	13.2	1.6	19.4	3.2

It is only possible to determine the dispersion or the mean-square deviation. The latter is the only statistical value which in this case must be controlled by the tolerance and is subject to evaluation in checking.

Such checking, although limited, is adequate for evaluating the accuracy of discrete instruments, providing the standard instruments of the given type have been appropriately tested.

This checking requires repeated comparisons of readings of the tested and reference instruments at each given point. Two methods of checking are possible: a) comparison at a constant reading of the tested instrument, b) comparison at a constant reading of the reference instrument. There is no theoretical difference in the two methods; hence, it is sufficient to examine, for instance, the first one.

In the absence of systematic errors the equations representing the i-th measurement at a given point will be:

$$\begin{aligned} a &= J_i + \alpha_i, \\ b_i &= J_i - \beta_i, \end{aligned} \tag{14}$$

where a, b_i are readings of the tested and reference instruments,

α_i, $(-\beta_i)$ are random errors of the same instruments. The minus sign in β_i was taken for the convenience of further calculations.

J_i is the value of the tested quantity at the i-th checking at a given point.

From (14) we have

$$\frac{\sum_1^n (a-b_i)^2}{n} \simeq \sigma_a^2 + \sigma_\beta^2 = \sigma_a^2(1+m^2). \tag{15}$$

The sum of the squared difference is divided by n and not (n−1) because it is assumed in advance that the centers of quantities α_i and β_i are at the zero point.

If in addition we know the values of the permissible dispersion $\sigma^2_{\alpha_0}$ of quantity α and $m_0^2 = \sigma^2_{\beta 0}/\sigma^2_{\alpha 0}$, the ratio of the permissible dispersions of quantities ω and β, the condition for approval at a given point will be the inequality

$$\frac{\sum_1^n (a-b_i)^2}{n} = \sigma_a^2(1+m^2) < \sigma_{a0}^2(1+m_0^2) = \sigma_0^2 \tag{16}$$

The real value of (m) remains unknown in checking. Therefore, it only remains to assume that the required value σ^2_α satisfies one of the following limiting inequalities obtained from (16) with m = 0 and m = m_0.

$$\left.\begin{aligned} \sigma_a^2 &< \sigma_{a0}^2(1+m_0^2) = \sigma_0^2 \\ \sigma_a^2 &< \sigma_{a0}^2 . \end{aligned}\right\} \tag{17}$$

If $m_0 > 1$ the limits for σ^2_α becomes inadmissibly wide. Hence, the value of m_0 must be at any rate smaller than one. It can be assumed that in many practical cases of checking it is permissible to take $m_0 = 0.5$; then the possible variations of σ_α will not exceed ~10% of the given value of $\sigma_{\alpha 0}$. For particularly accurate checking one could take $m_0 = 0.3$ for σ_α variations not to exceed ~5% or even $m_0 = 0.2$ for σ_α variations of ~2%.

In practical checking different methods are sometimes used. The tolerance is specified directly for the readings of the tested instrument which is equivalent to the requirement that with a given number of tests any difference should satisfy the condition

$$|a - b_i| < \Delta_0. \tag{18}$$

In other cases the tolerance is set on the spread (usually called the variation) which is equivalent to the requirement that the difference of the extreme terms of the variation series should satisfy the inequality

$$|(a - b_n) - (a - b_1)| < \Delta_0. \tag{19}$$

In the first case the limitation is imposed on the value of the largest term of the variation series and in the second, on the spread. In both cases, however, the quantity Δ_0, appearing in (18) and (19), is, at a given number of tests, a function of the permissible mean-square deviation. Hence, a rational selection of Δ_0 involves in any case the determination of permissible values of $\sigma^2_{\alpha 0}$ and m_0 by means of standard measurements.

As far as the technique of routine measurements is concerned it should be noted that evaluations by the largest term, or spread, are simpler for calculations but, however, less effective than those of the mean-square deviation method. Hence, the required number of observations for a given accuracy in this case will be larger than in evaluations by the mean-square or dispersion methods. Above remarks especially apply to checking based on formula (18). The same accuracy can be attained with this method if the number of tests is several times greater than with the mean-square deviation method.

The probable scrap can be found from the following considerations based on Equation (16).

Let us denote by $\varphi_n(x_n)$ the density of distribution

$$x_n = \frac{1}{n} \sum_1^n (a - b_i)^2, \tag{20}$$

assuming n to be equal to number of tests at each point. Then the formulas similar to (1-4) will assume the form:

$$\begin{aligned}
W_{11} &= \int_0^{\alpha_0} Q(\sigma_{\alpha\beta}) \left[\int_0^{\alpha_0 \beta_0} \varphi_n(x_n, \sigma_{\alpha\beta}) dx_n \right] d(\sigma_{\alpha\beta}), \\
W_{21} &= \int_{\alpha_0}^{\infty} Q(\sigma_{\alpha\beta}) \left[\int_{\alpha_0 \beta_0}^{\infty} \varphi_n(x_n, \sigma_{\alpha\beta}) dx_n \right] d(\sigma_{\alpha\beta}), \\
W_{31} &= \int_{\alpha_0}^{\infty} Q(\sigma_{\alpha\beta}) \left[\int_0^{\alpha_0 \beta_0} \varphi_n(x_n, \sigma_{\alpha\beta}) dx_n \right] d(\sigma_{\alpha\beta}), \\
W_{41} &= \int_0^{\infty} Q(\sigma_{\alpha\beta}) \left[\int_{\sigma_0^2}^{\infty} \varphi_n(x_n, \sigma_{\alpha\beta}) dx_n \right] d(\sigma_{\alpha\beta}).
\end{aligned} \tag{21}$$

If quantities $(\alpha_i - \beta_i)$ contained in (14) are distributed according to the normal law, the quantity

$$\frac{n x_n}{\sigma^2_{\alpha\beta}} = \frac{\sum_1^n (a - b_i)^2}{\sigma^2_{\alpha\beta}}$$

will be distributed according to the χ^2 law with n degrees of freedom, since it is assumed in advance that the center of distribution of quantities $(\alpha_i + \beta_i)$ is at the zero point.

Formulas (21) show that the probable percentage of checking scrap is a function of the number $\underline{n}$ of tests at each point and the distribution law of $\sigma_{\alpha\beta}$.

The development of a correct technique for checking measuring devices which have mainly random errors should be based on tables providing values for W_{11}, W_{21}, W_{31} and W_{41} of formula (21). The compilation of such tables is only possible when standard measurements are made which establish the distribution of quantities $\sigma_{\alpha\beta}$ and x_n.

Measuring devices with mainly random errors include in particular the so-called precise balances: analytical, standard balances of the 2nd and 1st category and metrological balances. In this particular case the error of the reference instrument β_i is practically absent. The checking of balances amounts to repeated weighing of a weight by a method which eliminates systematic errors (methods of Mendeleev, Borda, Gauss and Gidaspov). Therefore, instead of (14-16) the following relations should be used:

$$\left.\begin{aligned} m_i &= m+\alpha_i, \\ \bar{m} &= \frac{\sum_1^n m_i}{n}, \\ \frac{\sum_1^n (m_i-\bar{m})^2}{n-1} &< \sigma_0^2, \end{aligned}\right\} \tag{22}$$

where m_i denotes the result of a single i-th weighing. The rest of the reasoning remains the same including that referring to the checking scrap with the difference that quantity $\sigma_{\alpha\beta}$ is replaced by quantity σ_α.

Checking instruments with both systematic and random errors. The purpose of checking in this general case consists of two objectives: a) finding the constant systematic errors which consist of the deviation of the random error distribution centers from the given values at the set check points, b) evaluating the mean-square deviation which represents the possible random deviations.

The checking, of course, can only be done by means of repeated measurements. Equations representing the i-th test are

$$\left.\begin{aligned} a &= J_i+x+\alpha_i, \\ b_i &= J_i-y-\beta_i, \end{aligned}\right\} \tag{23}$$

where $\underline{x}$ and $(-y)$ denote systematic errors of the tested and reference instruments, the remaining notations being the same as before.

From (32) we have

$$x+y=\frac{\sum_1^n (a-b_i)}{n}+\frac{\sum_1^n (\alpha_i+\beta_i)}{n}= =\frac{\sum_1^n (a-b_i)}{n}-z_n. \tag{24}$$

The evaluation of checking scrap by means of systematic errors is complicated as compared with the case examined at the beginning of the article by the presence of the random variable $\underline{z}$ in the right hand side of Equation (24). The value of the quantity

$$\frac{\sum_1^n (a-b_i)}{n} = x+y+z_n \tag{25}$$

found in checking consists now of three random independent variables ($\underline{x}$ and $\underline{y}$ are random since they are concerned with the aggregate of instruments and z_n is random for the given check). At the same time the value of

$\frac{\sum_1^n (a-b_i)}{n}$ serves to evaluate $\underline{x}$, i.e., the serviceability of the instrument with respect to the systematic error.

Hence, reasoning similar to that used in the first part of the article leads to the following formulas, equivalent to (1-4) but referring to the general case under consideration.

$$W_{11}=2\int_0^{\Delta_x}\varrho(x)\left[\int_{(-\Delta_x+x)}^{\Delta_x-x}\varphi(y+z_n)d(y+z_n)\right]dx;$$

$$W_{21}=2\int_{\Delta_x}^{\infty}\varrho(x)\left[\int_{-\infty}^{-(\Delta_x+x)}\varphi(y+z_n)d(y+z_n)+\right.$$

$$\left.+\int_{(\Delta_x-x)}^{\infty}\varphi(y+z_n)\,d\,(y+z_n)\right]dx; \qquad (26)$$

$$W_{31}=2\int_{\Delta_x}^{\infty}\varrho(x)\left[\int_{-(\Delta_x+\Delta_x)}^{\Delta_x-x}\varphi(y+z_n)d(y+z_n)\right]dx;$$

$$W_{41}=2\int_0^{\Delta_x}\varrho(x)\left[\int_{-\infty}^{-(\Delta_x+\Delta_x)}\varphi(y+z_n)d(y+z_n)+\int_{(\Delta_x-x)}^{\infty}\varphi(y+z_n)d(y+z_n)\right]dx.$$

It is easy to see that the values of (W_{21} + W_{41}) calculated from (26) will be nearer to the corresponding values given in the first part of the article if the effect of the random variable z_n is small. Since this quantity is a function of the number of tests, and if the latter is sufficiently large this portion of the checking scrap can be evaluated from the formulas given in the first part of this article.

The previous reasoning on the evaluation of random errors holds in this case also, with the exception that, in this instance, it is necessary to take into account the dispersion of quantity z_n.

It follows from (23) that

$$(a-b_i)-(x+y)=\alpha_i+\beta_i,$$

but the real value of quantity (x + y) remains unknown and it must be replaced by quantity

$$\overline{x+y}=\frac{1}{n}\sum_1^n(a-b_i)=x+y+z_n.$$

Then

$$(a-b_i)-\frac{1}{n}\Sigma(a-b_i)=(a-b_i)-(x+y)-z_n$$

and hence

$$\frac{\sum_1^n[(a-b_i)-\overline{(x+y)}]^2}{n-1}=\sigma_a^2+\sigma_\beta^2+\sigma_{zn}^2. \qquad (27)$$

Therefore (16) should be replaced by the following:

$$\frac{\sum_1^n[(a-b_i)-\overline{(x+y)}]^2}{n-1}=$$

$$=\sigma_a^2\left(1+\frac{\sigma_\beta^2+\sigma_{zn}^2}{\sigma_a^2}\right)<\sigma_{a0}^2(1+m_0^2)=\sigma_0^2,$$

where

$$m_0^2 = \frac{\sigma_{\beta 0}^2 + \sigma_{zn}^2}{\sigma_{\alpha 0}^2}.$$

Correspondingly in (21) quantity $\sigma_{\alpha\beta}$ should be replaced by the quantity

$$\sigma_{\alpha\beta zn} = \sqrt{\sigma_\alpha^2 + \sigma_\beta^2 + \sigma_{zn}^2}.$$

Conclusions. Rational values of the permissible errors can be established only by analyzing the probable checking scrap. The latter is determined by technical and economic considerations which include: a) the permissibility of a certain small percentage of unsatisfactory instruments remaining in circulation, b) the permissibility of condemning a certain percentage of serviceable instruments, c) the cost of a checking method which reduces to the required small dimensions or eliminates scrap.

No general relation between the permissible errors in the tested and reference measures or instruments is possible.

A rational and reliable selection of permissible errors and methods of checking is only possible when sufficient data is available on the error distribution laws in the manufactured measures and instruments. The provision of such data should be one of the primary objects in testing standard instruments.

Everything stated above refers to large scale testing of mass produced measures and measuring instruments when the aggregate of both the tested and reference measures and measuring instruments is sufficiently large. Above methods of calculations, however, are applicable to small groups of reference measures and instruments. In that case, however, it is necessary to use the discrete distribution of probable error densities which corresponds to the given number of instruments and their errors. Such a case could occur in evaluating checking results in any laboratory with a small number of reference measures or instruments. Such an evaluation is, of course, only possible if the errors of the available measures are determined with sufficient accuracy by more accurate methods than those normally used in checking these measures.

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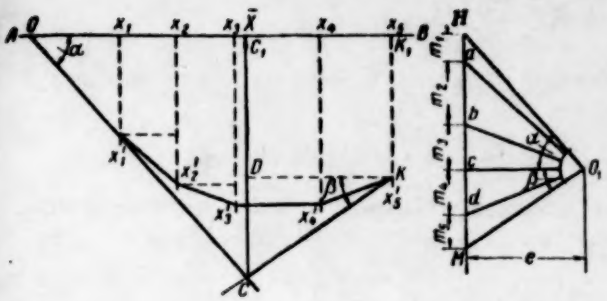
A GRAPHICAL METHOD OF DETERMINING THE STATISTICAL MEAN AND MEAN-SQUARE DEVIATIONS

D. V. Allab'ev

The similarity of formulas for determining the statistical mean and the center of gravity of a homogeneous body permits one to use, in working out observation results, the well-known graphical methods applied for determining the center of gravity.

Let there be a number of values x_1, x_2, x_3, x_4 and x_5 obtained as the result of measurements and let their frequencies be respectively m_1, m_2, m_3, m_4 and m_5.

For a graphical determination of a weighted mean it is possible to use the method of a funicular polygon. For this purpose one should measure out on a horizontal straight line AB (see the Fig.) from point O lengths corresponding to all the values of x_i in their proper order, and from an arbitrary point H in a direction perpendicular to AB plot in their proper sequence lengths corresponding to all the values of m_i. The ends and junctions



of the frequency axis are joined to point O_1 placed at an arbitrary distance e from HM. Then a straight line parallel to HO_1 is drawn from point O to its crossing point with the vertical line $x_1x'_1$ drawn from point x_1, and from point x'_1 a line parallel to aO is drawn to its crossing with the vertical $x_2x'_2$, etc. up to the crossing of the vertical $x_5x'_5$ with a line parallel to dO_1. From point K thus obtained a line parallel to MO_1 is drawn to its crossing with the extension of line Ox'_1. The thus obtained point C is projected onto AB.

The coordinate of point C_1 is the statistical mean of the measurements. If in the dispersion formula

$$\sigma^2 = \frac{\sum_{i=1}^{i=k} m_i(\overline{X}-x_i)^2}{\sum_{i=1}^{i=k} m_i}$$

we substitute $(\overline{X}_1 - x_1)^2$ by y_1 the expression for σ^2 will become similar to the formula for determining the statistical mean:

$$\overline{X} = \frac{\sum_{i=1}^{i=k} m_i\, x_i}{\sum_{i=1}^{i=k} m_i}.$$

Hence, the graphical method of determining the statistical mean holds for determining dispersion, providing y_1 is plotted as a linear quantity. For this purpose it is convenient to have a rule with a squared scale which is easy to make oneself. This allows one to plot $(\overline{X}-x_1)^2$ directly from the known values of $(\overline{X}-x_1)$ and to read directly off the graph, values of the mean square deviation.

The statistical mean does not usually coincide with the scale divisions of the measuring instrument. Therefore, in order to obtain a greater accuracy of calculations and use the graphical method in a more convenient way the following formula for the mean-square deviation should be used:

$$\sigma = \sqrt{\frac{\sum_{i=1}^{i=k} m_i(x_i-a)^2}{\sum_{i=1}^{i=k} m_i} - (a-\overline{X})^2},$$

where a is the rounded-off values of $\overline{X}$ to a multiple of the scale division.

By means of the graphical method we determine the value of

$$\sigma_1 = \sqrt{\frac{\sum_{i=1}^{i=k} m_i\,(x_i-a)^2}{\sum_{i=1}^{i=k} m_i}} > \sigma,$$

then we calculate σ from formula

$$\sigma = \sqrt{\delta_1^2 - (a - \bar{X})^2}.$$

It is possible to carry out the construction without the origin O. Then, it is necessary to draw two lines through point x_1 respectively parallel to HO_1 and aO_1.

In the absence of a squaring rule it is possible to use an ordinary rule and a table of squares.

The graphical method of determining the statistical mean and the mean-square deviation is speedier than the analytical method and prevents any gross errors occurring. It can be used for determining quantities of the form

$$x = \frac{\sum_{i=1}^{i=k} m_i^n \, x_i^p}{\sum_{i=1}^{i=k} m_i^n},$$

if m_1^n and x_1^p are plotted in the form of linear quantities.

LINEAR MEASUREMENTS

FUTURE DEVELOPMENT OF EQUIPMENT FOR MEASURING DISTANCES AND ANGLES IN ENGINEERING

N. I. Zimin and D. D. Malyi

The production of equipment for measuring linear and angular dimensions (with the exception of optical-mechanical devices) in special plants is given (in %) in Table 1.

The distribution of this output between the measuring instruments and more complicated measuring devices (in %) is shown in Table 2.

With due regard to the progressive increase in the share of "devices" in the total output, it must be admitted that the level achieved no longer corresponds to the present position and is utterly unable to meet the future needs of the engineering industry.

The forthcoming advances in technological processes, increased efficiency of machining operations, automation, specialization, structural changes in the production equipment, and other factors, call for a further improvement of measuring techniques.

This makes a further increase in the output of measuring devices, as compared with instruments, as well as the manufacture of devices for automation and mechanization of inspection operations, a basic and decisive direction in the development of the means of engineering measurements.

The output of gages for measuring distances and angles (in %) scheduled for the coming years is given in Table 3.

TABLE 1

Year						
1940	1946	1950	1955	1956	1957	1958
100	170	340	800	900	1000	1100

TABLE 2

	Year						
	1940	1946	1950	1955	1956	1957	1958
Instruments	91	77	69	63	63	62	62
Devices	9	23	31	37	37	38	38

TABLE 3

Year							
1958	1959	1960	1961	1962	1963	1964	1965
100	110	115	120	125	145	160	175

TABLE 4

Year							
1958	1959	1960	1961	1962	1963	1964	1965
100	115	130	140	150	180	205	225

The prospective figures for development rates in the manufacture of measuring devices and devices for automation and mechanization of inspection operations (in %) for the years 1959-65 are given in Table 4.

Only such a development process, which must be accompanied by a definite decrease in the share of low-grade measuring instruments in the total output, will lead to a general increase of the level of engineering measuring techniques.

The classification of equipment for linear and angular measurements scheduled for production in 1965 is given in Table 5.

An increased number of types of measuring devices being produced must become a further clear direction of development.

The production program of our specialized instrument manufactures covers a considerable variety of measuring and automation equipment.

Among many others the contact interferometers and profilograph -profilometers of the "Kalibr" works, the induction recording devices and the electroprofilometers designed by the Bureau of Interchangeability, a number of gear-measuring devices designed by the Bureau of Interchangeability and the Moscow Tool Factory, etc., deserve mentioning as products of highest class.

The multi-reading and ordinary lever-pinion dial gages made by the Leningrad Tool Factory have proved their high quality.

However, the list of high-precision, efficient and special measuring devices made by our industry is already inadequate to meet in full the requirements of the engineering industry.

The need to measure the components and their mating, with an error measured in microns or fractions of microns in workshop conditions, is becoming common.

TABLE 5

Gage type	1958 Share of total output, in %	1965 Share of total output, in %	Total output compared with 1958, in %
Total output	100.0	100.0	175.0
including instruments	62.0	50.0	140.0
devices	38.0	50.0	225.0
Calipers	19.0	17.0	155.0
Micrometers	10.0	10.0	160.0
Slip gages (gage blocks)	4.0	5.0	205.0
Instruments for checking flatness, straightness and angles	8.0	8.0	150.0
Limit gages	13.0	8.0	115.0
Other instruments	8.0	2.0	60.0
Universal measuring devices with 0.01-mm divisions	11.0	11.0	190.0
Universal measuring devices with an accuracy to within 1 μ and less	6.0	7.0	190.0
Angle measuring devices	5.0	6.0	210.0
Gear and gear tool checking devices	3.0	5.0	205.0
Automatic gaging and sizing devices	12.0	20.0	295.0
Other measuring devices	1.0	1.0	170.0

The data on the machining accuracy actually achieved in the engineering industry up to 1957 according to the report of a committee of the GNTK RSFSR are given in Table 6.

According to the provisional estimates the demand in the national economy for universal measuring equipment with an accuracy of measurement of one micron and fractions of a micron will steadily increase (Table 7).

TABLE 6

Method of machining	Accuracy actually attained in 1956
1. Turning on lathes	
a. ovality	0.003 mm
b. taper	0.006 mm
2. Boring on horizontal boring machines:	
a. center distances	0.01-0.015 mm
b. ovality of holes	0.005 mm
c. taper	0.008 mm
3. Cylindrical grinding:	
a. ovality	0.002 mm
b. taper	0.002 mm
c. surface quality	10-12th class
4. Internal grinding	
a. ovality of holes	0.001 mm
b. taper of holes	0.002 mm
c. perpendicularity of the end-face to the axis	0.002 mm
d. surface quality	9-10th class

The plans for the development of required designs and the basic schedules of the specialist instrument manufacturers for 1959-65 regarding the production of gages with a measuring accuracy of one micron or less provides for an increased percentage of high-precision devices in the total output volume.

In addition, the Bureau of Interchangeability worked out a list of types of measuring instruments and devices which will be needed in 1959-65; this provides for the production of a considerable number of various types of gaging heads for pneumatic gages, internal calipers, gear gages, angle and taper gages, sizing devices, devices for multiple gaging, and also of standard gaging units for use in automatic measuring devices and in the inspection equipment intended for universal use.

The axial-action high-precision measuring heads include microcomparator with 0.5 and 0.2 μ divisions and a small microcomparator (Micator). Despite its relatively wide measuring range (±0.05 mm) the Micator is small in size, which in many respects is advantageous when the device is used in conjunction with various inspection devices.

The gage is shown diagrammatically in Fig. 1. The plunger 2 moves in the guide sleeve 1; through a slit in its end a support is passed which is mounted on the flat spring 3. One end of the twisted strip 5 which carries the pointer 4 is rigidly secured, while the other end is fixed to the support 3. During the process of measurement the displacement of the plunger causes the support to move and the strip with the pointer to rotate. The deflection of the pointer is read on the scale 6 which has 70 1-μ divisions on either side of zero. The scale is fitted with special limit markers.

TABLE 7

Year						
1959	1960	1961	1962	1963	1964	1965
100%	105%	110%	120%	130%	140%	155%

On the section of the scale between plus and minus 30 divisions, the indication error of the gage is 0.5 μ, while outside this range the error is 1 μ. In the initial position the measuring pressure is 190 g and at the end of the range it reaches 240 g.

Another measuring device of the same type which must be put into production is the spring-optical gage, the so-called "Opticator" intended for comparing the measurements of external dimensions. The special design features of this device are that the pointer is

replaced by a reflecting mirror mounted on a twisted flat spring and that it has two colored-light filters for limiting the measurement range. The smallest scale divisions is 0.2 μ; the measuring range is ± 25 μ and the indication error ± 0.1 μ.

It is necessary, too, to organize the production of the lever-type comparator, the Minicator, with 1 to 2-μ divisions, the design of which is based on the same principle (the twisted spring).

The engineering industry also needs gaging heads with electrical contacts. These devices should be fitted with light signals, and it should also be possible to use them as ordinary scale gages.

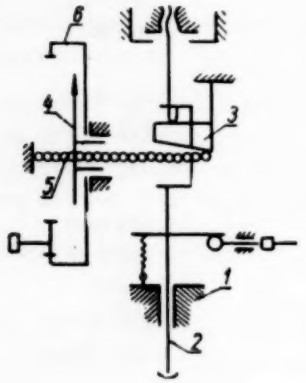


Fig. 1.

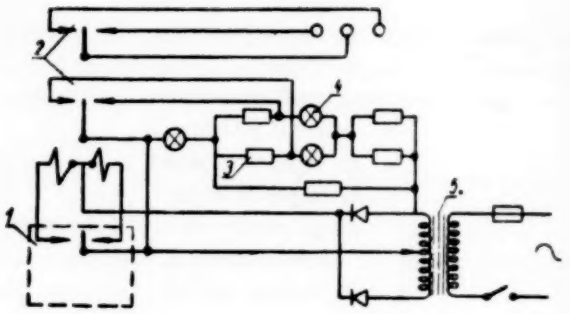


Fig. 2.

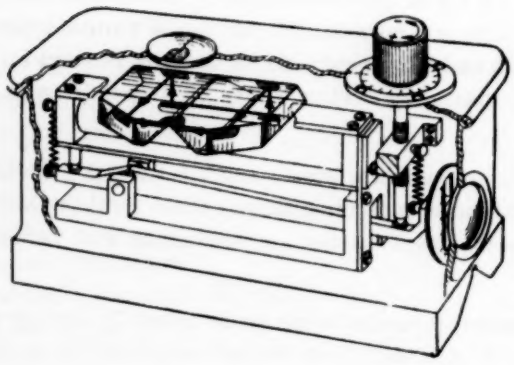


Fig. 3.

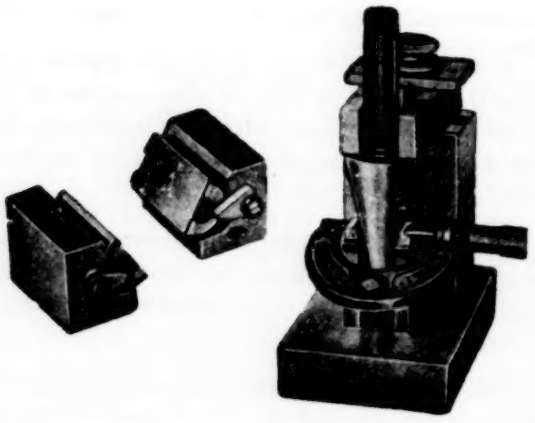


Fig. 4.

The schematic wiring circuit of such a gaging head is given in Fig. 2. The head 1 is connected by pressure contact into a dc circuit containing a standard polarized relay, the terminals 2 of which supply through an ohmic resistor 3 the voltage for filament lamps 4. The dc supply to the circuit is from a step-down transformer 5 and a selenium full-wave rectifier.

The side-action device with the scale located at the end, which was designed by the Bureau of Interchangeability and tested as a prototype should be put into large-scale production as soon as possible; the next design which should be developed in the one with the top scale.

The draft list of new types set up by the Bureau of Interchangeability includes other high-precision devices and, in particular, those based on induction and pneumatic principles.

The list of devices for internal measurements will be extended above all in the field of high-precision internal gages.

The micrometric level gage with optical scale (Fig. 3) and 0.01 mm divisions of the vernier scale will increase the accuracy obtainable in measuring the deviations from the horizontal position of flat or cylindrical surfaces, and in determining the deviations from straightness of horizontal surfaces. It can be expected that the measurement error of the device in its entire range will not exceed ±0.02 mm/m and ±0.01 mm/m within the range 3-11 mm/m.

The engineering industry feels a shortage in universal taper-angle checking devices. This caused the inclusion into a list of gages of one intended for the manufacture of blocks, the general view of which is shown in Fig. 4. Freely rotating semicylindrical members are placed onto the angular rests, the working surfaces of which are made with an accuracy of the order of 0.5 μ. The blocks are placed onto slip gages.* The flat surfaces of the semicylindrical members are in contact with the surface of the taper being inspected, the diameter of which is measured with a micrometer.

A number of plants, and in particular those of the heavy engineering industry, feel an acute shortage in well-designed sine tables. It is therefore imperative to take up the manufacture of compound double sine tables with a distance between rollers of 125 and 250 mm, and an area of 290 × 200 mm, and with provision for turning the table in longitudinal and transverse directions.

For heavy work, sine tables (Fig. 5) of two types are required: with an area of 1200 × 1200 mm and a roller distance of 1000 mm, and a lighter type with an area of 600 × 600 mm and a distance between rollers of 500 mm, and a maximum angle of 60°.

In the draft type-list of measuring equipment particular attention is being paid to increasing the output of gear-measuring devices; this is urged by the need for putting into effect the new GOST specification relating to gearing.

New equipment received by the industry in recent years includes devices for the inspection of the tooth direction, radial concentricity and other parameters of straight-tooth and helical spur gears and bevel gears. The engineering industry also received devices for checking the correctness of the lead of worms and hobs, of their profile, and of the worm pitch; and also machines for a complete double-profile checking of gears for correct meshing.

However, the number of types and the output figures of gear-gaging devices made by our industry are clearly inadequate, especially as far as the equipment for the inspection of helical precision gears, internal gearing, gear-cutting tools and machines are concerned.

The estimated increase in the demand for gear measuring equipment is given (in %) in Table 8.

The list of the required types of gear-gaging devices set up by the Bureau of Interchangeability is designed to cover the inspection of small and large-pitch precision gears, the quality of meshing by measuring elements specified in the new GOST specification for gearing, and the high-precision gear-cutting tools and instruments.

Some of the devices scheduled for production are already being designed at the Bureau of Interchangeability; prototypes are in construction of devices for measuring the cyclic errors of helical spur gears, the circular pitch of the spur and bevel high-precision gears, for the inspection of hobs and of the differential gear trains of hobbing machines, etc.

With a few exceptions, the design of measuring instruments and devices now in large-scale production in this country is of roughly the same quality as that of foreign equipment. However, the production methods, and in a number of cases the quality, call for an improvement. The work in this field is also one of the basic directions of the development of the measuring-equipment industry in the near future.

Without listing in detail the items of measuring equipment whose quality must be improved, we would like to stress the need for a gradual reexamination, type-by-type, of machining allowances, with the object of reducing them. This measure is especially feasible in view of the forthcoming improvements in the equipment of manufacturers of special equipment.

Along with putting into effect the more-or-less complex measures required, which in the near future will improve the general standard of engineering measurement techniques, the scientific and design organizations will be faced with a number of scientific and technical problems which will to a considerable extent affect the future rate of development and production standards in the engineering industry.

*Gage blocks.

TABLE 8

Year						
1959	1960	1961	1962	1963	1964	1965
100	105	110	115	130	150	160

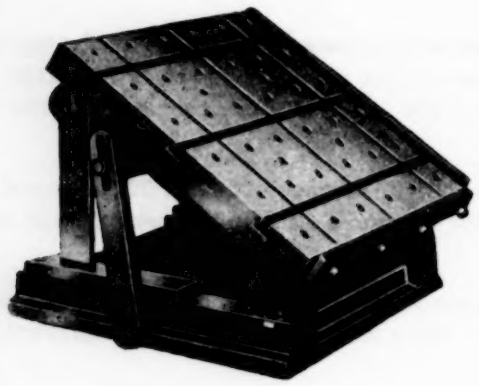


Fig. 5.

These problems include:

1. The development in the heavy engineering and machine-tool industries of means of production and methods of measurement which are based on new physicotechnical principles. In solving these problems particular attention should be paid to optical, photoelectrical, hydraulic and other methods of inspection.

The objects of inspection are: large circular cylindrical joining-elements with a diameter of up to 50 m, slideways up to 100 m long, alignment of heavy stationary structural members and various components during assembly, inspection of large gears, lead screws etc.

2. The development of means and methods of checking the kinematic accuracy of the fit of joints, in order to eliminate the use of models of these connections (standard gages, gaging gears, lead screws, etc.) which are expensive and difficult to produce when a high degree of accuracy is required.

The main objects of inspection are precision gears, worms, screw thread, etc.

3. The development of new types of gaging heads and transducers with a minimum dynamic error, and also of means and methods for the remote inspection of dimensions.

AUTOMATION OF INSPECTION IN THE ENGINEERING INDUSTRY

E. R. Dvoretskii and D. D. Malyi

Automatic inspection is employed mainly: a) when the final inspection of finished components must be wholly completed away from the place where they were machined, or when the components are made in completely automatic factories, departments, or lines and b) in production inspection, during the machining and processing of components on machine tools.

The ball-bearing, automobile and tractor industries employ inspection – sorting automatic machines made in this country which show great objectivity and accuracy of inspection, and are highly productive.

However, despite the positive results obtained in the operation of automatic gages in the inspection of components and finished articles away from the work place, cases are known when the automatic machines made for this purpose have not been employed in production.

The investigation of a number of such cases showed that replacement of labor-consuming complete final inspection by efficient automatic machines is not always an economic proposition.

In a number of cases the stabilization of the manufacturing process and other organizational and technical measures eliminates the need for a 100% inspection of finished components, making an automatic inspection unnecessary.

Thus, an automatic inspection of finished components away from the workplace is justified mainly when the inspection is accompanied by the sorting of articles into dimension groups for subsequent selective assembly. In this case the possibility of increasing the machining tolerances offers an additional advantage in the form of reduced production costs.

At an automated piston factory, in the automated, mass-production, ball-bearing department and in the automatic lines producing piston pins, electric motor rotor shafts, etc., the automatic machines designed by the Bureau of Interchangeability of the Standards, Measures, and Gaging Equipment Committee perform efficiently, with sufficient stability, and the required accuracy, such complex functions as are called for in checking various dimensions and properties, such as the inspection of dimensions and sorting of pistons according to the pin bore into groups with 2.5-μ difference in diameters, the determining of the excess piston weight for the removal of the weight surplus, the checking of dimensions and the elimination of rejects in the production of bearing rings. Further, automatic machines already in use perform the final inspection of bicycle-chain components, radio components, spark-plug threads, etc.

The Bureau of Interchangeability's automatic machines for selecting components for antifriction bearings and for the inspection of the clearance in semiassembled bearings are considered to be of particularly advanced design.

Both machines are combined in a single unit and are set to assemble bearings in the following way: on the basis of the measurement of the mean diameter of a pair of ring tracks, performed with an accuracy of $\pm 1.5\ \mu$, the first machine "calls out" the required number of balls of the suitable dimension while the second machine, after determining with a mean-square error of $\pm 1\ \mu$ the mean of the radial clearance in two radial directions, rejects the semiassembled bearings in which the radial clearance exceeds the specified value.

Admitting the high effectiveness of the use of automatic devices in completely automatic plants we would like to point out that the need for a systematic improvement of the technical standard of these and other engineering plants presents to automatic inspection, apart from high productivity and accuracy, a third basic requirement: automatic inspection must ensure not only the sorting of accepted components into dimension groups and separate the rejects, but also, which is most important, control the production process in order to eliminate the causes of unsatisfactory work.

After drawing conclusions from the gaging results, the automatic-control devices must warn machines that the components are approaching the limit of tolerances, or that rejects are possible due to the exceeding of some other parameter.

This implies that the automatic inspection equipment should be active, and as a rule, installed on the machine tools, immediately following them or at the conveyors linking two stations.

Only this line of development will lead to a sharp increase in the accuracy and productivity of inspection, a reduction in the size of the inspection apparatus and of the losses due to rejects.

It must be admitted that we have done very little in the field of automatic sizing.

Not until a year or two ago did the Cheliabinsk Instrument Factory begin the production to order, and at extremely high prices, of automatic sizing equipment for cylindrical and surface-grinding machines.

A very small number of leading engineering plants are producing automatic sizing equipment of their own design and for use with existing grinding machines.

The majority of existing machine tools and of machines now in production are not suitable for control by automatic sizing devices, especially as far as small accurate displacements of the working elements are concerned. For this reason the small number of sizing devices which are at our disposal are usually used in the engineering industry only for the indication of dimensions.

This situation calls for the immediate implementation of a number of measures aiming at a radical change in the development of automatic sizing methods.

Among the foremost tasks is the design of advanced standard equipment for automatic sizing.

This is the line which the Bureau of Interchangeability was pursuing in designing a number of gages for the above purpose.

The BV-711 device is intended for automatic sizing or gaging of components machined on 3153A, 3152, and 3162 cylindrical grinding machines.

The gaging head of the device carries an indicator and a double-range contact with two signal lights. A pivot link connects the gaging head with the grinding wheel guard.

An electronic relay controlled by the opening and closing of electrical contacts feeds impulses into electric circuit of the machine tool, thus operating the tool and component feeds and the machine as a whole.

The gage covers the diameter range 3-250 mm. The measurement error remains within 0.005-0.01 mm in gaging, or 0.002-0.005 mm in automatic sizing.

The device is being manufactured by the Cheliabinsk Instrument Factory.

The BV-962 unit, which is based on the induction principle, is intended, in its original form, for controlling the dimensions of smooth cylindrical shafts, 20-60 mm in diameter, during grinding on the KhSh-202 grinding machine, with an error of $\pm 3\,\mu$.

During the grinding process the work is contacted by the adjustable top contact 1 (Fig. 1) which is fixed in the body, and the bottom contact 2 which is shaped as a lever and acts upon the armature 3 of the induction transducer. The gaging unit is suspended on the flat spring 4 to the column 5, whose slideway is attached to the machine table.

The indicating unit of the gage has a scale with large 1 μ divisions, and three contacts which can stop the roughing and finishing feeds and the infeed according to the actual dimensions of the work. The scale can be used for setting all three contacts to the master gage with correct dimensions.

The gage is very accurate in operation, insensitive to vibrations, including those due to ovality of the work (since it produces a mean of the periodically changing dimensions) and has a small gaging unit which is well protected against the action of the coolant; its indicator can be installed at the most suitable place on the machine.

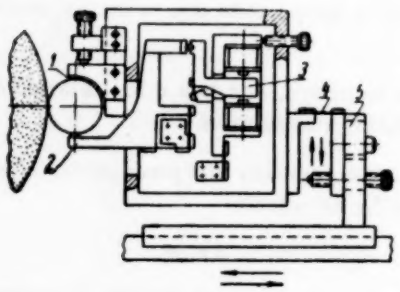


Fig. 1.

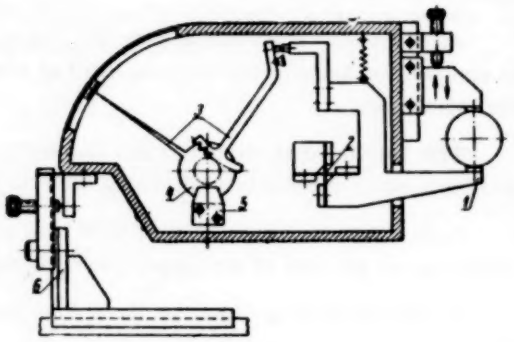


Fig. 2.

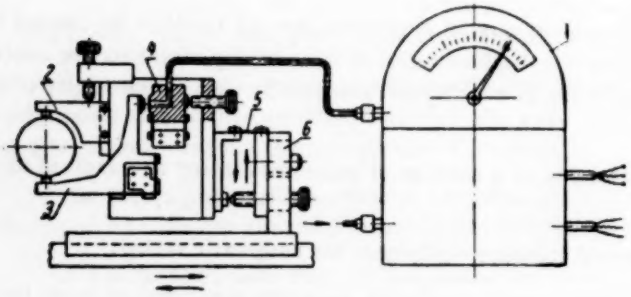


Fig. 3.

The BV-904 and BV-907 devices are intended for the continuous indication of the external diameters of stepped components with diameters ranging from 5 to 60 mm, during grinding on cylindrical grinding machines; the gaging error is $\pm 3\,\mu$.

During the grinding process the component is in continuous contact with two contact points (Fig. 2). The bottom contact 1 has the shape of a lever which turns on two springs 2, and actuates the gaging head 3 incorporating a lever-pinion mechanism. In order to eliminate vibrations the disk 4 of the gage pointer rotates between the shoes 5 of an electromagnetic brake. The gage is mounted on supports 6 which are fixed to the worktable, and whose number corresponds to the number of the diameters of the workpiece. An inspected component is used for setting the device.

In the BV-907 gage the moving pointer is replaced by a disk which moves in relation to the stationary pointer; it has a scale with 0.01 mm divisions for rough grinding and for finish grinding a scale with 0.002-mm divisions.

The BV-928 air gage is designed for gaging or sizing of 8-60-mm diameter components during the cylindrical grinding; its error is ±1-±3 μ.

The gage (Fig. 3) has a differential pneumatic gaging head combined as a single unit 1 with filters, stabilizers, scale, signal lights, and electrical equipment.

The floating holder, which automatically adjusts itself to the work, carries the measuring contacts, an adjustable upper contact 2 which is fixed to the body, and the lower contact 3 which is shaped as a lever and is suspended on flat springs; its end is shaped to cover the measuring jet 4.

The holder is suspended on the flat spring 5 to the support 6, the slideway of which is attached to the machine table.

The BV-903 gage which has a measuring range 15-60 mm, is intended for the indication of the diameter of stepped workpieces during cylindrical grinding; the error of the gage is ±3 μ.

The gaging unit (Fig. 4) is designed as an adjustable three-contact bracket.

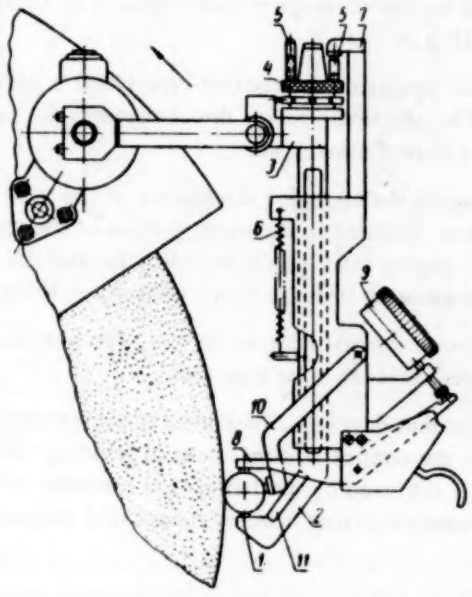


Fig. 4.

The bottom (base) contact 1 is attached to the bottom end of the bracket 2. The top end of the bracket carries the sleeve 3 intended for fixing the gage on a lever-type shock-absorber, and the turret 4 with adjustable stops 5, each of which is intended for setting the gage to one of the diameters of the work.

The spring 6 moves the bracket until one of the turret stops contacts the stop 7 which is fixed on the body.

The top gaging contact moves the pointer 9 by means of the lever 8.

The third (side) contact is mounted on the movable stop lever 10 whose end rests on the plate 11 of the bracket.

A master component is used for setting the gage, which is effected by adjusting the turret stops until the same indicator reading is obtained for all diameters.

During operation the readjustment of the gage from one diameter to another is effected by turning the turret, which puts into action the corresponding stop.

Foreign companies, like ourselves, use various methods for the transmission of the measuring impulse into the actuating signal in automatic sizing units for cylindrical grinding.

There is now a tendency, especially in the USA, to replace electric contact heads, and even pneumatic gaging heads, by electric induction or capacitance units.

Some designs which are widely used in Europe deserve particular attention, especially the gages for sizing manufactured by EAM and Movalimit which are based on the capacitance principle.

The American Industrial Gage Company manufactures automatic sizing units based on the capacitance principle which, according to reports from the plants using them, enable the grinding of solid bronze shafts with an accuracy of 1 μ, at the same time meeting stringent requirements regarding ovality and taper.

The "Justimat" and "Finotor" type gages are gaining in popularity abroad (German Federal Republic). According to the manufacturers, the error due to the wear of the gage is less than 1 μ, while the diametrical error, which can occur in the machining of a mass-produced article, does not exceed ±3 μ.

A very advanced line of development in the design of sizing equipment is represented by the combination of the direct control unit (in the machining zone) with a unit located away from the machine. In this case the unit installed away from the machine is arranged to set the machine according to an average of results obtained in gaging several components.

Such adjusting devices which operate away from the machining zone ensure the elimination of temperature errors.

Considering that the functions of these gages can include the sorting of accepted components into various groups, the setting of the machine to any of the several diameters being ground, and the stopping of the machine in the case of a tool failure, it becomes obvious that such automation of the sizing function in cylindrical grinding will in future find extensive use.

• • •

The Bureau of Interchangeability has also developed a number of standard designs for work-sizing in surface grinding.

The BV-912 gage is intended for use with surface grinders, and in particular with the 3722, 3B71, and 3724 machines; it is manufactured to order by the Cheliabinsk Instrument Factory.

The measuring ranges are: minimum range 0 –250 mm and maximum range – 0-400 mm. The measuring error in automatic sizing is ±3-±5 μ, and in gaging from ±5 to ±10 μ.

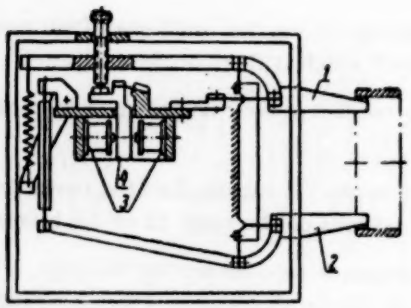


Fig. 5.

During automatic operation the contact-type electric gaging head controls, by means of an electronic relay, the changeover for roughing to finishing feeds, and stops the machine.

In automatic gaging the changing dimensions of the work are observed on an indicator installed in the upper portion of the measuring head. In this case the gaging takes place periodically, and the machine table stops when the measuring stylus is above the surface being gaged.

The original electric circuit adopted for the gage enables the inspection of interrupted surfaces to be effected.

The sizing equipment developed by Forster (German Federal Republic) also enables the control of dimensions in grinding interrupted surfaces. This is achieved by the lifting and lowering of the spindle of the single-contact gaging head by means of a magnet at 30-second intervals until the required dimension is reached.

Difficult requirements which must be met by internal grinding, and the absence of an efficient means of control in this field determine the need for the introduction of work-sizing gages in these operations.

The Bureau of Interchangeability developed a standard unit for this purpose, which can be adapted to various types of machines.

Figure 5 shows diagrammatically the BV-967 unit intended for sizing of smooth cylindrical holes in components machined on internal grinding machines, and in particular on the 3A250 and 3B250 grinders.

The measurement range is 50-200 mm; the gaging error, ± 2 μ.

The design of the gage is based on the use of the induction method with a self-balancing bridge. The measuring styli 1 and 2 which have carbide points are connected to the coils 3 and the armature 4 of the induction gaging head.

The variations in the distance between the tips occurring during the grinding process effect variations in the size of the clearance between the coils and the armature of the gaging head.

The dimension being measured is read on the scale of an indicator located some distance from the gaging head.

The unit gives signals for stopping the roughing and finishing feeds and for end of operations.

This gage differs from the BV-962 gage only in its gaging unit, which is designed for measuring holes. The induction transducer , the measuring contact head and the electrical equipment of this unit are the same as those used in the BV-962 gage. Thus, the indication part of these gages is standardized.

Work-sizing in centerless grinding operations is as yet not widely used.

The Bureau of Interchangeability has designed and constructed the following work-sizing gages for the 3G182 centerless grinding machine, which are now being tested.

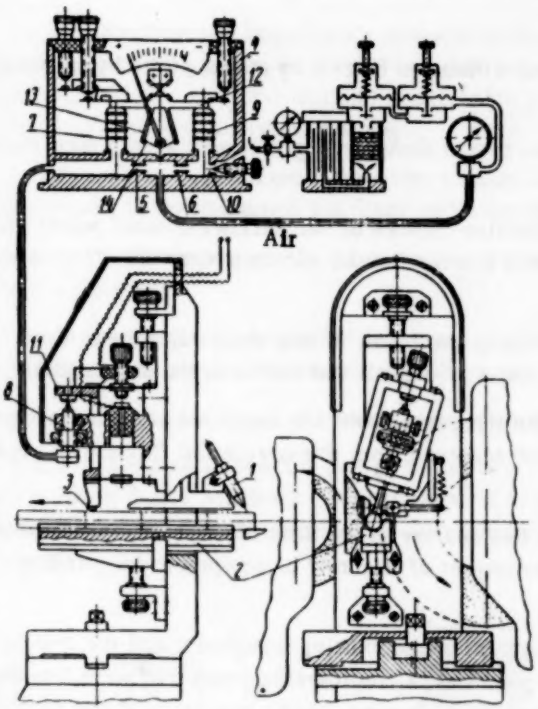


Fig. 6.

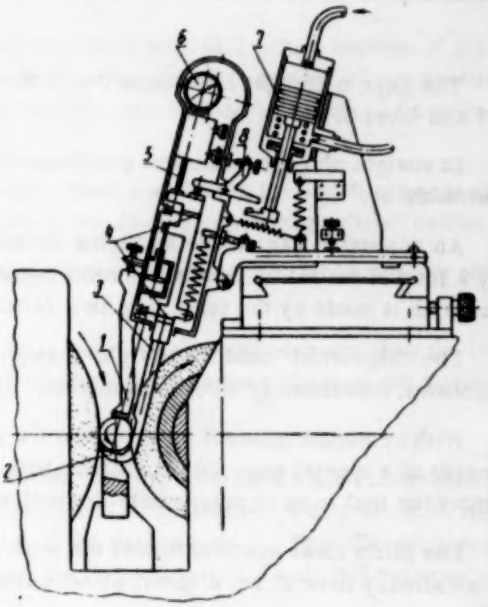


Fig. 7.

The BV-893 unit is intended for the automatic sizing of the diameter of components with smooth and interrupted surfaces after their machining on automatic centerless grinding machines. The gage feeds back signals which actuate the automatic resetting as soon as the "set dimension" has been exceeded and also signals the appearance of rejects. The setting range is 5-25 mm. The gaging error is $\pm 2\ \mu$.

The equipment is shown diagrammatically in Fig. 6. The machined workpieces cleaned with an air jet supplied from the nozzle 1 are fed onto the rest 2; here they are gaged by means of the needle 3, whose vertical position determines the degree of opening of the air nozzle 8, which is connected with the pneumoelectrical transducer 4. This is fitted with three adjustable electrical contacts which send signals which operate the grinding-disk setting mechanism.

The compressed air is first fed to the top jets 5 and 6; from the jet 5 it flows to the bellows 7 and jet 8, and from the jet 6 to the bellows 9 and the adjustable outlet jet 10. The measuring pressure in the bellows 7 depends on the variations of the clearance between the end face of the nozzle 8 and the plate 11. The bellows 7 and 9, deformed by the difference of pressure, turn the block 12, which by means of the lever 13 and the thread 14 is connected with the indicator pointer.

The BV-918 gage fitted with an electric two-limit transducer is intended for the automatic gaging and sizing of workpieces of the second grade of accuracy machined on automatic centerless plunge-grinding machines.

The gaging head (Fig. 7) has the shape of a bracket which is placed into the recess of the actuating ring. The top contact 1 is stationary while the bottom contact 2 is linked with the measuring stylus 3 which moves on flat springs 4. The movements of the tracer are transmitted to the measuring stylus 5 of the transducer and to the indicator 6.

TABLE 1

Year							
1958	1959	1960	1961	1962	1963	1964	1965
100%	115%	128%	142%	156%	182%	200%	225%

TABLE 2

Year						
1959	1960	1961	1962	1963	1964	1965
100%	150%	215%	285%	440%	520%	600%

The gage is brought into contact with the component and withdrawn from it by means of the hydraulic cylinder 7 and lever 8.

In straight-through centerless grinding,equipment similar to that shown in Fig. 6 is now widely used abroad for work-sizing.

An adjustable gage made by Sigma for small-scale production consists of two parallel contact points which carry a jet and are set by means of master capsules. This unit is attached to the electropneumatic "Sigmatrol" gage which is made by the same firm in a variety of models.

The "Sigmatrol" controls straight-through centerless grinding machines, effects their adjustment, sorts components, continuously records dimensions, operates sound and light signals and indicates the dimensions.

With centerless grinders operating on the plunge principle the components are inspected after the machining by means of a special gage; in accordance with the information received from this device,the "Sigmatrol" operates the machine tool so as to compensate the tool wear.

The fairly close examination of the work carried out in this country in the field of sizing equipment shows that we already have at our disposal an adequate number of prototypes of this kind of equipment for grinding machines.

In connection with the problems involved in the improvement of the existing equipment and the development of new types for the control, during operation, of all grinding processes, a considerable amount of work lies ahead on the design and the putting into production of sizing gages for lathes, honing, boring and gear-cutting machines.

The actual introduction of work-sizing equipment now depends mainly on the machine-tool manufacturers, who should pay special attention to the fitting of modernized and new machines with sizing attachments.

In its endeavour to foster the putting into production of the newly designed automatic sizing equipment, the Bureau of Interchangeability estimated the expected demand for this type of gage and fixed, in cooperation with the specialist instrument manufacturers, the necessary rate for expanding production.

The proposed rates of development of automatic sizing equipment are given in Table 1.

Provided that the manufacturers of machine tools and other machines submit their requirements concerning the design and production of sizing equipment in time, their production will develop as follows (Table 2).

The proposed rates of development of production will ensure the provision in 1965 of the necessary equipment for fitting the required number of grinding, honing, gear-cutting, screw-thread cutting and boring machines and special and automatic lathes with work-sizing gages.

SIZE CONTROL IN COMPLEMENTARY GRINDING

A. V. Vysotskii

In all cases when the clearance or interference between mating components (sleeve – shaft) is limited by very rigid tolerances of the order of 2-5 μ, the need to ensure full interchangeability considerably increases the production costs.

In mass production, such accuracy of mating is achieved by selective assembly, which means that the shaft and sleeve produced with relatively wide tolerances are sorted according to their dimensions into several groups (from 3 to 50). The sleeve of each group is assembled with the shaft of the corresponding group which enables the required accuracy of mating to be obtained.

For medium and large-batch production, selective assembly may meet with difficulties because of the shortage in certain groups of mating components, which is unavoidable when the total number of components is relatively small. In individual and small-batch production such matings are obtained by means of labor-consuming and expensive individual fitting.

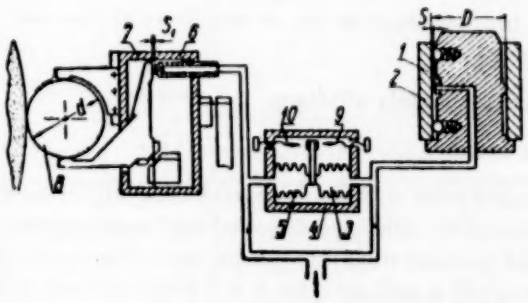
In such cases the most satisfactory method is complementary grinding where the mating dimensions of the components being machined are made to fit the mating dimension of the other component produced earlier.

Pneumatic equipment is most suitable for complementary grinding as it enables the problem to be solved in the simplest way.

Since the sizing equipment for external cylindrical grinding is more reliable and accurate than the internal grinding gages, it is preferable to make the external diameter of the shaft fit the existing hole in the sleeve.

The process is shown diagrammatically in the figure.

The finished sleeve 2 is placed onto the jet plug 1 of the instrument; the clearance S and, consequently, the pressure in the bellows 3 of the chamber 4 depends on the diameter D of the sleeve. The pressure in the bellows 5 of the chamber depends on the clearance S_1 at the jet 6 of the gaging head 7. This clearance depends, in turn, on the dimension d of the shaft 8 being ground.



On closing the contact 9 of the chamber, the machining of the shaft 8 stops; the contact 9 must be adjusted in such a manner that the clearance (or interference) D–d is of the required size. The dimension d depends on the diameter D of the sleeve placed on the plug.

If another sleeve 2, the diameter D of which is smaller than that of the previous component, is placed onto the plug then the clearance S is smaller, the pressure in the bellows 3 increases and the pressure in the bellows 5 must be increased in order to close the contact 9. In order to achieve this the component 8 must be ground to a smaller dimension d which reduces the clearance S_1. The placing of a sleeve with a larger diameter D onto the jet plug closes the contact 9 and the grinding of the component 8 is stopped at a larger d.

The contact 10 of the chamber is used in changing from rough to finish grinding.

ON SMALL INDICATOR GAGES

F. P. Volosevich

As long ago as 1955 we wrote (Izmeritel'naia Tekhnika, No. 3, 1955) about the serious shortcomings of the small indicator gage made by "Kalibr" (GOST 5584-50) which render it absolutely unsuitable for use on a marking-off plate in measuring coordinates or for fitting to a height gage.

However, although we have heard that new small lever gages are being prepared for production, they have not yet been manufactured.

The Bureau of Interchangeability of the Standards, Measures and Measuring Equipment Committee compiled in 1957 a specification for small lever-pinion gages with 0.002 and 0.01 mm divisions, which describe two types of gages. Considerable attention is paid to the small gage BV-894 which is as yet not used in our industry.

In the explanatory note to the tentative specification, the Bureau of Interchangeability state that certain technological difficulties were encountered in the manufacture of small gages which led to the adoption of increased indication errors. We think, however, that the increase of errors should remain within the limits which do not affect the quality of the device.

In the near future it will be necessary at last to take up the manufacture of small high-precision and accurate lever gages which meet workshop requirements.

GAGING DEVICES WITH SPRING SUPPORTS

A. M. Bykov and P. I. Kuz'michev

The use of flat springs in gaging equipment is particularly useful in the case of high-precision measurements under shop conditions, since flat springs have no backlash or friction, show no loss of sensitivity and are not subject to wear; all these factors ensure a good stability of gaging.

Such equipment is simple to manufacture, easy to use and adequately efficient.

In the following we describe the gages developed by the authors.

Device for the inspection of threaded studs. In the manufacture of stud which close-mating high-strength thread considerable difficulties are encountered in the inspection of the effective diameter and in sorting the components into dimension groups. With the existing method of dividing studs into groups, the tolerance of the effective diameter for each group is relatively small. For example, the tolerance for 6 × 1 threaded studs of the second class is 0.101 mm, and the effective diameter tolerance of one group of the same dimension (with close-mating thread) is 0.02 mm. The studs with the second class thread could be inspected by means of ordinary screw ring gages but the attempts to use these rings for the close-mating thread failed. Close-tolerance ring gages are difficult to make, rapidly become worn and fail to ensure the required accuracy. In addition, the method of inspecting the thread by means of rings is inefficient.

The authors of this article proposed a gage for the inspection of the effective diameter, based on the use of flat springs (Fig. 1). The gages were built and have proved their good quality in prolonged operation.

The gage consists of the body 1 supported on four legs, which arrangement enables its use on the table without additional fixing. A dial indicator is fixed by means of the tangential clamp 3 on the support 2 attached to the body. The hanger with the rest 4 is fixed on four flat springs 5 to the support. This arrangement enables the hanger to move only in a strictly upright position and compensates any noncoincidence in the pitch of the half-rings which are placed in the rests T. The movable hanger 6 is fixed on four flat springs to the body of the

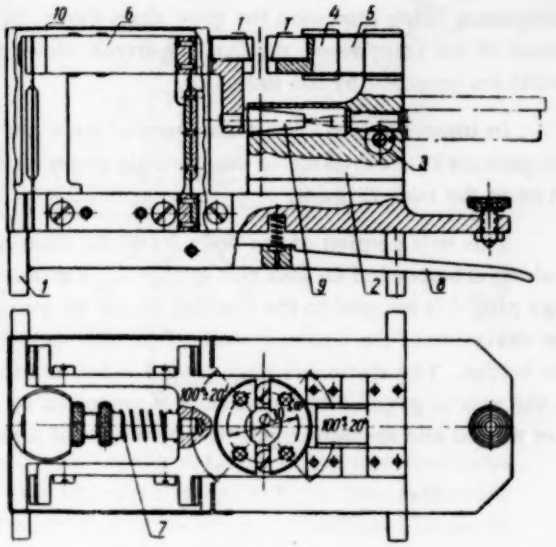


Fig. 1.

instrument. This enables the hanger to move only in a strictly horizontal position. The special design feature of vertical springs is that the central part of the spring is fitted with plates on both sides, which render the system rigid and stable without affecting the easy movements of the hanger. The measuring pressure on the half-rings is produced by the coil spring 7. The half-ring gages set into the rests T correspond to the thread of the work. The device is adjusted to a master component by setting the indicator to zero. After setting, the half-rings are secured in position by means of screws. For the introduction and removal of the work the movable hanger 6 is lifted by means of the lever 8. The deviation of the effective diameter of the component's thread is transmitted to the indicator by means of the stop 9 which is pressed into the hanger. The instrument is protected by the casing 10.

Device for gaging center distances. A gage with a split plug and floating frame is successfully used, under workshop conditions, for measuring the center distances on components, with an accuracy of up to 0.01 mm, and also for the selection of components, with an accuracy of up to 0.005 mm.

The gage (Fig. 2) consists of the body 1, the floating frame 2 which is suspended in the body on four flat springs 7, the split plug 3 which is fixed to the body, and the plug 4 which is secured to the frame by means of nuts 6 with hexagon socket heads, and also a chuck-type clamping member 5 for the indicator.

The split plug (Fig. 3) consists of the body 1 with a spring jaw, a spring 2 and a screw 3 which control the contact pressures that eliminate any clearance.

Since the contact area between the jaw and the work is large and the plug is thoroughly polished, no scratches or other defects are left in the holes of the components being inspected. The jaws open in a plane perpendicular to

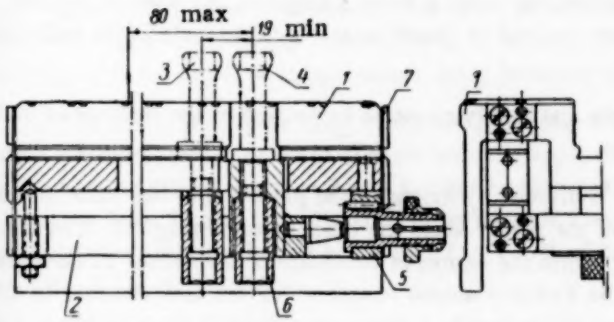


Fig. 2.

the axis which passes through the centers of both holes being gaged. The variations in the size of holes in the component, within the permissible tolerances, regardless of how large they are, produce no error in the measurement of center distances.

The gage plugs are selected according to the diameter of the holes in the work being inspected. The center distance is adjusted by moving the plug along the body groove. After securing the plug gage with nuts, the indicator is set at zero by means of a master gage which is a plate with

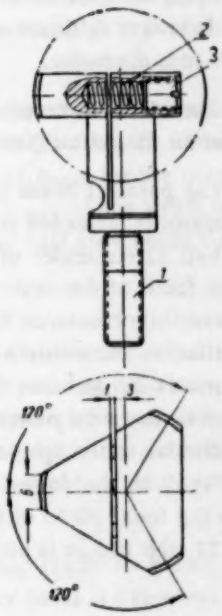


Fig. 3.

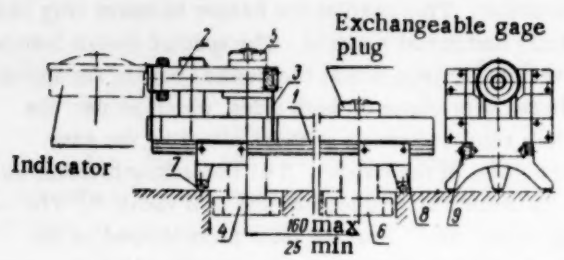


Fig. 4.

holes, the diameters and the center distance of which are equal to the dimensions of the component being inspected. In order to eliminate the clearance in the holes of the component being inspected, the gage plugs move, by means of the component, the floating frame whose movements are recorded by the indicator.

In inspecting the center distances of large and heavy components it is advisable to use portable gages which are set upon the work (Fig. 4).

This unit consists of the body 1 and the floating frame 2 which is suspended on four flat springs 3. The movable gage plug 4 is secured to the floating frame by means of nuts 5. The displacement of the frame, which is equal to the deviation of the center distance from the specified value, is transmitted to the indicator which is clamped in the holder. The stationary gage plug 6 is secured in the frame groove with nuts, after the instrument has been set to the master gage. The instrument is supported on the workpiece at three points on movable legs 7 and 8, which are moved and secured in position by means of screws 9 to fit the flat face of the component being inspected.

INTERFERENCE METHOD FOR THE EXAMINATION OF THE SURFACE WAVINESS OF BALLS

Iu. V. Kolomiitsov

The existing mechanical methods of measuring the depth of local irregularities or "waves" on the surface of balls (for example the method of prism and indicator) are labor-consuming and fail to produce the accuracy often required. The microinterferometers of various types which are successfully used in checking the quality of finish of ball surfaces cannot be used in examining the regularity of their shape, since at any given moment this instrument enables the examination of only a very small area. Spherical test glasses are also not very suitable for this purpose because of the rapid wear of their surfaces and the need to have a large set of glasses of various radii. It is also difficult to use the contactless interference method in checking lenses [1] especially for balls of less than 10 mm diameter.

The interferometer described below enables a simple and highly accurate inspection of the surfaces of balls of different diameters (from 1 to 15 mm).

The parallel beam leaving the objective 6 (Fig. 1) is divided by means of the plate 7 into two parts; one of these beams is reflected on the semitransparent surface of the plate, while the other passes through it. The center of the ball 11 coincides with the focus of the objective 9, while the center of curvature of the mirror 12 coincides with the focus of the objective 10. This enables rays of the first and second beams which are concentrated in the focuses of the objectives 9 and 10 to fall upon the wall and the mirror in a direction normal to their surfaces, and after reflection to return along the same paths. After being combined by the plate 7, both beams pass into the observation tube and interfere with one another. In its top position the objective 14 produces two images of the orifice 5 in the field of view of the eyepiece. Both images are made to overlap by moving the ball in directions perpendicular to the optical axis, whereupon the objective 14 is lowered into its bottom position (which is indicated in Fig. 1 by the dotted line). Here the objective 14 projects the image of the plane tangential to the mirror 12 into the focal plane of the eyepiece. It is in this plane that the interference is examined. By connecting the mirror 17, the image is projected by the objective 18 onto the photographic film 20.

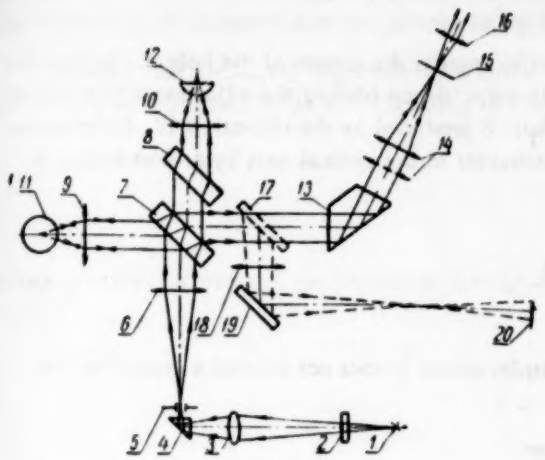


Fig. 1. Schematic diagram of the interferometer. 1) Mercury vapor lamp; 2) light filter separating the green line of mercury; 3) condenser lends; 4) prism; 5) diaphram with pin hole combined with the focus of the objective of the collimator 6 which, for the sake of simplicity, is indicated by a short straight line (the same as other objectives); 7) parallel-sided plate with semitransparent reflecting layer; 8) compensating plate; 9) and 10) identical micro-objectives; 11) ball being examined; 12) standard spherical mirror; 13) prism; 14) objective of the eyepiece tube; 15) and 16) grid and eyepiece of the micrometer; 17) removable mirror; 18) micro-objective; 19) mirror; 20) film.

Owing to the use of a monochromatic light there is no need to achieve a zero difference in the paths, which makes the resetting of the interferometer, when changing the ball diameter, much simpler. The visible area of the ball is proportional to the ball diameter and to the relative opening of the objective 9. In the prototype instruments the ratio of the objective diameter to its focal length is 1:1.5. The diameter of the section being examined is 0.33 times the ball diameter. By turning the ball it is possible to examine the various sections of its surface.

If the ball is placed accurately and the surface section being examined is of a regular spherical shape, then the interference produces a uniformly illuminated field of view. A slight movement of the ball in any direction perpendicular to the optical axis produces straight equidistant interference bands. A displacement of the ball along the optical axis causes a distortion of these bands, or the appearance of rings. Thus a general distortion of the bands, or the number of rings, are determined by the position of the ball, and do not characterize the correctness of its shape. The local deviations of the surface from a perfect sphere cause the deformation of the wavy surface reflected from the ball, and local distortion of the interference bands; these distortions, expressed as a percentage of the band width, do not change when the ball moves. By estimating visually or by measuring by means of a micrommeter eyepiece the "sag" of the local distortion of the bands which cannot be removed, and relating the obtained values to the width of these bands, it is possible to determine the depth of the corresponding irregularities of the surface in terms of wavelengths of light or in microns. If the widths of the bands are equal, then the accuracy of measurement is 0.1-0.2 of the band width, or 0.03-0.05 μ. Balls having a bad surface cause an intense deformation of the bands, the width of adjoining bands becomes nonuniform and the measurement accuracy drops to 0.5 of the band width or to 0.13 μ. Experience shows that this method enables the examination of balls with the depth of irregularities lying between 0.03 and 1 μ.

The minimum width B_{min} of the irregularities being considered depends on the diameter D of the ball, since the diameter of the field of view which is approximately 30 mm remains the same for all balls. The irregularities whose visible width is 2 mm are easily identifiable. The corresponding values of B_{min} for the diameters D varying from 1 to 15 mm, lie within the range 0.02-0.3 mm. The maximum value B_{max} of the width of the irregularities can be taken as being equal to a half of the diameter of the section of the ball area being considered, i.e., $B_{max} = 0.16\ D$.

The optical system of the interferometer being described is similar to that of the Twyman interferometers developed for the examination of the photocamera and microscope objectives [2, 3]. Our system differs from that of Twyman in that we have replaced the flat mirror mounted on one of the branch paths of the above interferometer by the objective 10 and the spherical mirror 12. If the radii of curvature r and r_0 of the surface of the fall 11 and the mirror 12 are equal, then both branches of the interferometer are identical and the differences in the paths Δ_0 and Δ of the axial are inclined pairs of rays show no differences. Owing to this fact the hole 5 can be made large, which provides a sharp interference picture with a high general brightness.

If $r \neq r_0$ then the similarity of the interferometer branches is somewhat distorted. It can be shown that with a perfect adjustment of the interferometer the difference of these differences in the ray paths is expressed by the following approximate equation

$$\delta_0\Delta = \frac{f^2}{4}\,\frac{|r-r_0|}{r\,r_0}\,\epsilon^2, \tag{1}$$

where f is the focal length of the objectives 9 and 10 and ϵ is the angular dimension of the hole 5. In practice the value $\delta\Delta$ is of great importance because of the inaccuracy in coincidence (during the adjustment process) of the center of curvature of the mirror 12, and the image of the hole 5 produced by the objective 10. Calculation shows that a displacement of the mirror 12 in a direction perpendicular to the optical axis by a short length b, increases the difference of the path differences by the value

$$\delta'\Delta = bf\frac{|r-r_0|}{r\,r_0}\,\varepsilon. \tag{2}$$

In adjusting the interferometer it is easy to ensure that displacement b does not exceed a quarter of the image of the hole 5, i.e., the value $\epsilon f/4$).*

In this case $\delta'\Delta = \delta_0\Delta$ and the total value of $\delta\Delta$ becomes

$$\delta\Delta = \delta_0\Delta + \delta'\Delta = \frac{f^2}{2}\,\frac{|r-r_0|}{r\,r_0}\,\varepsilon^2. \tag{3}$$

In order to obtain a sharp interference, the following conditions should be fulfilled: $\delta\Delta \leq \lambda/4$ (see [4]).

This gives the permissible angular dimension of the hole 5

$$\varepsilon < \frac{1}{f}\sqrt{\frac{\lambda\,r\,r_0}{2|r-r_0|}} \tag{4}$$

and the permissible diameter of the hole

$$d = \varepsilon F < \frac{F}{f}\sqrt{\frac{\lambda\,r\,r_0}{2\,|r-r_0|}}, \tag{5}$$

where F is the focal length of the collimating objective 6.

Thus, the brightness of the observed interference which is determined by the permissible size of the light source, is the greater, the smaller is the absolute value of the difference $r-r_0$ and the larger are r and r_0. Therefore, it is more difficult to obtain a bright and sharp interference picture for small balls than for large components. For example, assuming that F = 50 mm, f = 10 mm and r_0 = 2.5 mm we obtain for r = 0.5 mm, d ≤ 0.06 mm and for r = 6 mm, d ≤ 0.17 mm.

It is desirable to have the mirror 12 interchangeable, so as to be able to vary the r_0 value. However, owing to the fact that this mirror must be installed very accurately, it is difficult to produce a design which enables it to be changed rapidly. A simpler design has one fixed spherical mirror, but with two interchangeable diaphragms with holes 5 of different diameter. However, in this case a lower brightness of the interference bands must be accepted when balls with widely different diameters are inspected. Experience showed that for r_0 = 2.5 mm it is possible to obtain a sharp and at the same time sufficiently bright interference for balls with diameters ranging from 1.5 to 15 mm.

*For this purpose the surface of the ball 11 is placed into the focus of the objective 9, which is indicated by the appearance in the field of view of the eyepiece 16 of a sharp image of the hole 5 which remains stationary when the ball is removed perpendicular to the optical axis. Thereupon both hole images are overlapped by shifting the mirror 12.

From (5) it also follows that the permissible diameter of hole 5 is proportional to the relation F/f. However, an increase of F or a reduction of f, with the relative opening of the objective 9 remaining unchanged, produces no increase in the brightness of the picture being observed.

In fact, the amount of light energy E entering the interferometer is proportional to the square of d and to the square of the effective relative opening of the objective 6, i.e.,

$$E = kd^2\frac{p^2}{F^2} \tag{6}$$

where p is the diameter of the objective 9 and k is the coefficient of proportionality. Taking into account (5) we obtain

$$E < k\left(\frac{p}{f}\right)^2 \frac{\lambda r r_0}{2|r-r_0|}. \tag{7}$$

Thus, if the size of the light source is selected correctly the brightness of the observed interference (with its diameter remaining constant) is proportional to the square of the relative opening of the objective 9, and is independent of the focal length F of the objective 6. In the instrument being described $p:f = 1:1.5$ and the brightness of the picture is entirely satisfactory. A further increase of the relative opening will hardly serve any useful purpose since it will tend to make the objectives 9 and 10 more complicated and will lead to a deterioration of the quality due to errors in assembly.

An important point in the operation of every interferometer is the selection of the plane in which the interference is observed. Usually the plane selected is the same as that of the surface being examined, but in the case of the interferometer being described, this condition is not always observed, which necessitates each time an investigation of the extent to which the deviations from this rule are permissible.

As has already been pointed out, the interference is observed on a plane tangential to the pole of the mirror 12. If $r \neq r_0$, then the plane N, in which the interference appears lies at a distance $r-r_0$ from the surface of the ball being inspected, which is shown diagrammatically in Fig. 2.

The rays reflected from various points of the ball surface pass through the point O of the plane N. Figure 2 shows the axial ray 1 and the rays 2 and 3 which come from extreme points of the hole 5 in the diaphragm (Fig. 1). The combined action of surface irregularities is observed at point O. The diameter x of this section can be found from the condition

$$\frac{x}{\overline{AB}} = \frac{|r_0-r|}{r_0}.$$

But $\overline{AB}$ is the diameter of the image of the hole 5 of the diaphragm produced by the objective 4 (9 in Fig. 1). Therefore $AB = \epsilon f$ and

$$x = \frac{\varepsilon f\,|r-r_0|}{r_0} = \sqrt{\frac{\lambda r\,|r-r_0|}{2r_0}}.$$

For example, for $r_0 = 2.5$ mm and $r = 7$ mm, $x = 0.013$ mm, i.e., the irregularities at intervals of 0.01 mm cannot be examined separately. But the irregularities of the type being inspected are of a smooth type and are located at considerably larger distances from one another, which proves that the chosen method of observation of the interference is acceptable. Experience shows that even very big changes in focusing (caught by the movement of the objective 14 along its axis) do not affect the local distortions and the sharpness of the interference bands.

SUMMARY

The device and method described enable a clear presentation of the profile of the ball surfaces being examined, and the measurement of the depth of local deviations of this surface from a perfect sphere, with an error of 0.03-0.1 μ, to be made. An observation of rings is useful for a rapid qualitative assessment of the ball, while the measurement of the depth of local irregularities on its surface is determined with a higher accuracy from the distortions of the "straight" bands. The method can be recommended for the selective inspection of balls during their manufacture and also for use in the assembly of precision bearings. The use of this method can considerably increase the accuracy of the investigation of deformations on the surfaces of balls during the operation of the bearings.

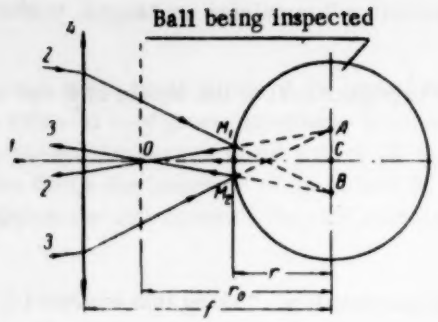


Fig. 2.

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MEASURING OF CONTACT GAPS BY THE ABSOLUTE INTERFERENCE METHOD

I. T. Uverskii

The measuring instruments operating on the contact principle (microcomparators with 0.1 and 0.2 μ divisions, ultraoptical indicators, optical projection indicators with 0.2 μ divisions, contact interferometers, etc.) are now widely used for accurate length measurements.

During the process of gaging, these devices must exert upon the object (Fig. 1) a pressure sufficiently small so as not to cause a permanent deformation at the point of contact, but sufficiently large to ensure the required stability of readings. The error introduced by measuring contacts is

$$\Delta = \varepsilon + \eta,$$

where ϵ is the accidental error due to the instability of contact gaps δ, and η is the systematic error caused by variations in the size of the contact gap at the end of the length being measured.

The accidental error ϵ is due mainly to dirty contacts and to the variations of the measuring pressure of the gage. These causes can be easily eliminated and ϵ reduced to any desired value.

For the comparative measurements

$$\eta = (\delta_0' + \delta_0'') - (\delta_n' + \delta_n'').$$

where $\delta'_0 + \delta''_0$ is the sum of two contact gaps at the "zero" setting of the instrument to the master gage, and $\delta'_n + \delta''_n$ is the sum of two contact gaps with the object being measured in the instrument.

For absolute measurements

$$\eta = \delta_0 - (\delta'_n + \delta''_n),$$

where δ_0 is the contact gap at the "zero" setting of the instrument when its measuring surfaces touch one another.

The regular error η depends, as a rule, on the physical properties of the bodies in contact and the height of the microirregularities of their surfaces. It is zero if

$$\delta'_0 = \delta'_n \text{ and } \delta''_0 = \delta''_n, \text{ or } \delta_0 = \delta'_n + \delta''_n.$$

If η exceeds 10% of the permissible measurement error it can no longer be ignored and must be determined, and either taken into account or sufficiently reduced by altering the contact conditions.

In this connection for each typical case of precision measurements the contact gaps δ must be calculated by the Hertz method or measured, as was done by the author during his investigations in the field of inspection of precision gage blocks.

The following contacts were investigated:

1. Corundum tips: spherical with R = 14 mm, and flat with a diameter of 3 mm (5 contacts).
2. Corundum tips: spherical with R = 14 mm, and gage blocks from 1-20 mm (6 contacts).
3. Steel tips, spherical with R = 8 mm, and gage blocks from 7 to 20 mm (5 contacts).
4. Corundum tips: spherical with R = 2.5 mm, and gage blocks from 2 to 9 mm (4 contacts).

The gage blocks conformed to the specification for first-class gages (OST 85,000-39). The deviation of the flat contacts from flatness did not exceed 0.06 μ. Local irregularities of the sphere of tips with R = 14 mm did not exceed 0.2 μ. The quality of surface finish of contact surfaces was never below that specified for the 13th class (GOST 2789-51).

The contact gaps were measured by the absolute interference method in wavelengths of the yellow line of the krypton spectrum (λ = 0.587 μ) by means of a Kester interference comparator with a special weight attachment.

The attachment (Fig. 2) consists of the body 1 with the table 2, whose position is set by means of the screws 3. The protruding part of the table has a V-shaped notch which takes the knife edge of the rocker 4. The front end of this rocker carries the mirror 5 and a pin to which the tip 6 being tested is attached. The rear end of the rocker lever has a screw thread and carries the counterweight 7.

The arm 8 is suspended between the side plates of the body and carries the slide 9 with the center member 10, and is held in position by means of the screw 11. The free end of the arm carries the scale pan 12, with the lever ratio of the arm being 2.

The centerpiece remains in the wide hole in the mirror 5 but is not in contact with it. Its bottom point is supported in a countersunk hole in the lever pin, and the top point in a hole in the slide which adjusts the centerpiece in such a manner that its axis and the axis of the pin in their working position strictly coincide. The limit of sensitivity of this device is about 0.1 g.

The test piece is placed on the table of the device under the spherical point; it is a gage block supported on a flat plate (in order to prevent flexure) or a flat tip on a support with a highly polished surface which represents a kind of continuation of the relatively small measuring area of the tip.

During the measurements the tip 6 is lowered onto the test piece, the lever 4 is balanced by means of the counterweight 7, a weight of 0.5 g is carefully placed upon the pan 12, and the device is adjusted until the interference bands parallel to the guide lines of the device appear on the images of the surfaces of the mirror 5 and the test piece.

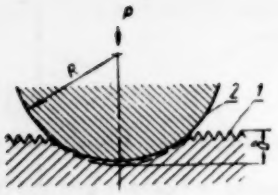

Fig. 1. Mechanical contact.
1) Gage block; 2) tip of the measuring device; δ contact gap.

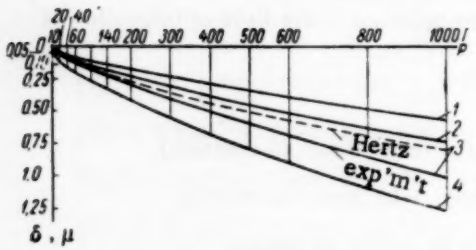

Fig. 3. Corundum R 14 mm – corundum R ∞; 2) corundum R 14 – steel R ∞; 3) steel R 8 mm – steel R ∞; 4) corundum R 2.5 mm – steel R ∞.

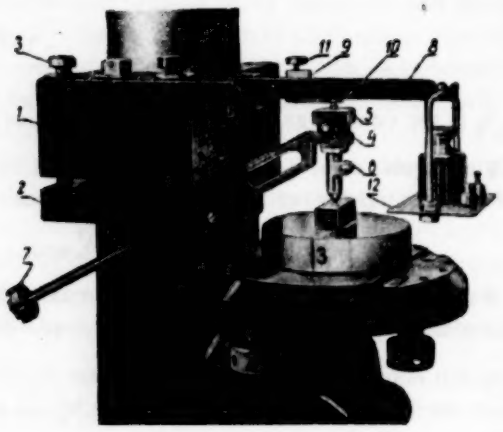

Fig. 2.

The interference bands were observed at the contact loads: 1-2; 1-4; 1-10; 1-20; 1-40; 1-60; 1-100; 1-140; 1-200; 1-300; 1-400; 1-500; 1-600; 1-800 and 1-1000 g. The contact gap δ was determined for each load range from the displacement of the interference bands in relation to the guide line of the device. The size of the gap was determined as an arithmetic mean from 3-5 readings; the measurement error varied according to the stability of the gap, but never exceeded ±0.03 μ; an instability of the gap was not observed at loads below 200-300 g.

The measurement results are given in Fig. 3.

The diagram shows firstly, that the larger the radius of the sphere and the hardness of the contacting bodies, the smaller the gaps and their variations; second, the gap curves for the contact steel, with R from 8 mm to ∞, constructed from the experimental data and plotted from the values obtained with the Hertz equation, are identical. The deviation can be explained by the incorrectness of the coefficient of the Hertz equation, which in our opinion should be increased by 27%.

During the measurements the cleanness of the contact surfaces was regularly checked by means of the MII-5 microinterferometer (500 × magnification). These checks revealed no defects on the contact surfaces; no permanent deformations were observed; after the load was removed the shape of the deformed microirregularities was fully restored, even in the case of the tip with R 2.5 mm and the 1000 g load.

SUMMARY

The accidental error ϵ which is introduced by the measuring contacts is contained in the variations of readings on the gage scale, and requires no special investigation.

Systematic errors η introduced by the measuring contacts must be calculated or measured for each type of measurement and taken into account during the accurate determination of dimensions in precision measurements.

In measuring gage blocks (OST 85,000-39) on the contact devices, the optimum results were obtained with spherical corundum tips with R 14 mm, operating with loads of up to 300 g. In these cases the contact pressures for gage blocks are only a third to a fifth of the permissible values, while the contact gaps δ are so small and constant that the measurements can be made with the utmost precision.

The measurements of δ showed that for best contacts $\eta = 0$ when the lengths of these gages is determined by the method of comparison, and $\eta = 0.06\ \mu$ when it is determined by the absolute method.

THEORY AND PRACTICE OF GAGING PSEUDOROUNDNESS

L. A. Boldin

Workpieces whose cross section is a pseudocircle are referred to as pseudoround, i.e., while not being perfect circles, they have constant dimensions when measured in any direction between two parallel planes (Fig. 1). The noncircularity of such workpieces cannot be detected by ordinary methods of measuring diameters; it can be detected and measured only by an indirect method, most easily by inspection by means of vee-blocks or sleeves (gage rings).

A pseudocircle can be constructed graphically with any odd number of crests, starting with three. For example, the faces of a three-crest pseudocircle (Fig. 1a) are formed by circular arcs with radii R_{pr}, while the crests are struck with radii r_{pr} from the apexes O_1, O_2, O_3 of the so-called base triangle. In measuring the diametral dimensions of the figures thus obtained, the same value of D_{gag} will always be obtained

$$D_{gag} = R_{pr} + r_{pr} = \text{const}, \tag{1}$$

since the gaging planes will be tangential to the arcs of the profile and, consequently, perpendicular to both radii which at the points of contact always begin at the same common center.

In constructing any other pseudocircle the centers of the arc-shaped crests will always be located in the apexes of the base pentagon (Fig. 1b), heptagon, 9-angle, 11-angle, etc. figures. The shape ofthe base polygon can always be irregular (Fig. 1c) provided that the condition of equality of the straight line connecting the apexes ($O_1O_4 = O_1O_3 = O_2O_5 = O_2O_4 = O_3O_5$) is met. The limit of any pseudocircle is the perfect circle obtained by the equality of radii $R_{pr} = r_{pr}$, on one hand, and the geometrical figure constructed of arcs with sharp crests meeting the condition $r_{pr} = 0$, on the other.

According to the published data, the three-crest shape is predominant in out-of-round workpieces. In investigating the process of external centerless grinding the author found that the pentagonal forms are often found alongside the triangular shapes. The intermediate form having three large and two small crests (Fig. 1c) is, however, encountered most frequently.

The quantity ϵ defining the pseudoroundness is the difference between the diameter of the circle struck about the profile of the cross section D_{in}, and the diameter D_{gag} of the workpiece, obtained by measuring the distance between two parallel planes:

$$\epsilon = D_{in} - D_{gag}. \tag{2}$$

Consequently, the "mating" diameter of pseudoround workpieces, which is D_{in}, is larger than the diameter of the same workpiece measured in the ordinary way.

For subsequent consideration it is essential to determine some relations between the elements of pseudocircles. We have introduced the conception of the radius of displacement r_{dis}, which is equal to the radius of a circle struck through the apexes of the base figure. Then, striking from the apex O_1 (Fig. 1a) an auxiliary arc O_2FO_2 with a radius equal to the side of the base triangle $O_1O_3 = O_2r_{dis}\ \sqrt{3}$, we can write

$$OA = OO_3 + O_3A = r_{dis} + r_{pr}$$
$$OB = BC + CF + OF = \varepsilon + r_{pr} + (r_{dis}\sqrt{3} - r_{dis}).$$

Since OA = OB, it can be written for a three-crest pseudocircle.

$$\varepsilon = (2 - \sqrt{3})r_{dis} = 0{,}268 r_{dis} \tag{3}$$

For a regular five-crest pseudocircle (its elements are marked by a line on the right)

$$\varepsilon' = 2\overset{\circ}{(}1-\sin 72^\circ)\, r'_{dis} = 0{,}098\, r'_{dis} \qquad (4)$$

The pseudoroundness is measured most frequently by rotating the workpiece in vee-blocks. However, the value $h_2\alpha$ thus obtained, which is determined from the maximum deflection of the gage pointer, is not the actual value of the pseudoroundness of the workpiece (Fig. 2), with the difference being dependent on the angle of the vee-block and the shape of the noncircular section.

The equation relating the amount of pseudoroundness indicated by the gage with the length of the sides of the base figure of a regular three-crest section is derived in [1]. However, since this value cannot be measured directly the equation is of no interest for practical applications.

The following shows the derivation of the equation obtained by the author for this case.

The meaning of symbols used in Figs. 2a and 2b:

h_2 is the pseudoroundness as indicated by the gage in gaging the workpiece with an actual pseudoroundness ϵ in a vee-block with an angle 2α and

H_1 and H_2 are distances from the reference plane (laid horizontally through the line of intersection of the side surfaces of the block) to the highest point of the workpiece in one of its three positions (i.e., when the height of the base triangle coincides with the bisectrix of the block).

$$h_{2\alpha} = H_2 - H_1 = (BM+MC)-(BF+FC)+ \\ +2CO_1-(O_1A-O_1T). \qquad (5)$$

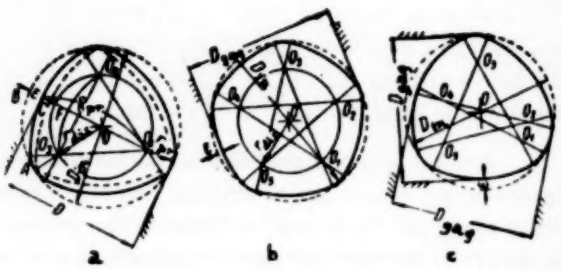

Fig. 1.

Each of the four terms of the right side can be expressed by means of the basic elements of the system

$$(BM+MC)=(NL+LM)\ \mathrm{ctg}\alpha + LO_2\sin\alpha = r_{pr}\ \frac{1}{\sin\alpha} + \\ + r_{dis}\frac{\sqrt{3}}{2}\mathrm{ctg}\alpha,$$

$$(BF+FC)=(O_2K-O_2F)\frac{1}{\sin\alpha}+O_2F\sin\alpha = \\ = r_{pr}\ \frac{1}{\sin\alpha} + r_{dis}\sqrt{3}\frac{1}{\sin\alpha} - r_{dis}\frac{\sqrt{3}}{2}\mathrm{ctg}\alpha.$$

$$CO_1 = O_1O_2\sin 60^\circ = \frac{3}{2}\, r_{dis},$$

$$(O_1A-O_1T) = R_{pr}\ - r_{pr}\ = r_{dis}\sqrt{3}.$$

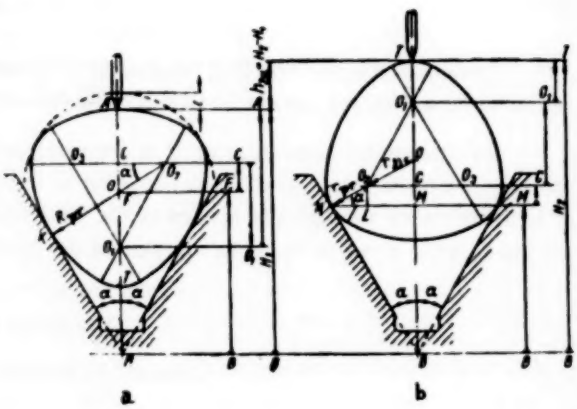

Fig. 2.

By substituting the values obtained in (5) we get

$$h_{2\alpha} = r_{dis}\sqrt{3}\left[\left(\mathrm{ctg}\alpha - \frac{1}{\sin\alpha}\right) + (\sqrt{3}-1)\right] = \\ = r_{dis}\sqrt{3}\left(0.732 - \mathrm{tg}\frac{\alpha}{2}\right) \qquad (6)$$

Taking into account (3)

$$h_{2\alpha} = \left(4.733 - 6.466 \operatorname{tg} \frac{\alpha}{2}\right)\varepsilon. \tag{7}$$

The Equation (7) is only correct for angles $2\alpha \leq 120°$, since it is derived under the assumption that in the position shown in Fig. 2, the workpiece touches the block with its rounded crests rather than with its faces. However, this range includes all practical applications of the block.

A similar conclusion can be drawn for a regular five-crest noncircular body. With the same denotations the final equation takes the following shape

$$h'_{2\alpha} = \left(12 \operatorname{ctg}\alpha - 19{,}4\frac{1}{\sin\alpha} + 17{,}5\right)\varepsilon'. \tag{8}$$

The Equation (8) can be used for blocks with angles $72° \leq 2\alpha \leq 144°$ in which the workpiece again touches the block with its rounded crests.

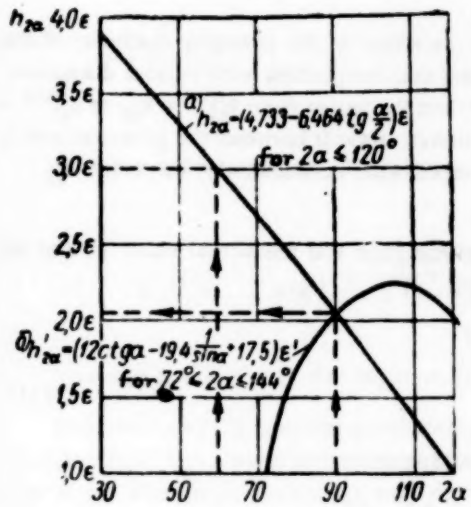

Fig. 3.

In order to make their use easier the Equations (7) and (8) are presented as graphs in Fig. 3. From the curve a we find directly for the most frequently used blocks with 60° and 90° angles

$$\text{for} \quad 2\alpha = 60° \quad h_{2\alpha} = 3\varepsilon, \tag{9}$$

$$\text{for} \quad 2\alpha = 90° \quad h_{2\alpha} \simeq 2\varepsilon, \tag{10}$$

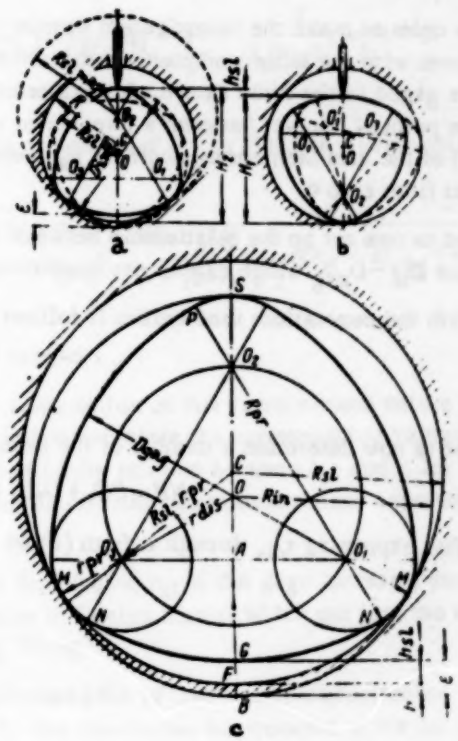

Fig. 4.

i.e., when the measurement is carried out on a 60° block the dial reading is twice, and on a 90° block three times the actual value by which the workpiece is out of round.

It follows from the comparison of both curves that only the 90° vee-blocks should be used in gaging the pseudoroundness, since the Equation (10) is fulfilled here for both three-crest and five-crest noncircular workpieces.

In the publications of recent years it is mostly recommended that components which are not perfectly circular should be gaged in sleeve gages (gage rings). However, the use of this method is limited to the gaging of a

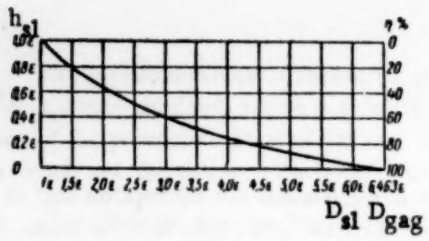

Fig. 5.

large number of workpieces since the range of application of costly precision gage sleeves is limited. In addition, no references are to be found as to the size of measurement errors, which may be considerable.

In the following the results are given of an investigation which was carried out by the author into the method of gaging by means of sleeve gages.

The gage shows the actual size of the deviation from roundness only when the work is rotated in a sleeve with the diameter equal to D_{in} (Fig. 4a). This diameter is different for different workpieces. Thus, the great majority of components in the batch being inspected will have a more or less large clearance in the sleeve with the result that for them the reading h_{sl} of the device will be different from the actual ϵ value. Figures 4a and 4b show the component with a noncircular cross section inside the sleeve in two extreme positions which determine the amount by which the workpiece is out of round. This also shows that the reading remains the same irrespective of whether the work is supported on a crest and held in an unstable vertical position or lies freely in the sleeve, since the expression

$$H_1 = D_{gag} = \text{const.}$$

applies to any workpiece.

In order to make the investigation simpler we have considered the effect of the changing diameter of the gage sleeve with the same workpiece, rather than the actual case when the components with various diameters D_{gag} are gaged in the same sleeve, which in principle is the same. When R_{sl} varies from $R_{sl}^{min} = R_{in}$ to $R_{sl}^{max} = R_{pr}$ the point of contact between a three-crest component and the sleeve travels between the points M and N (Fig. 4c) of the arcs MN; correspondingly, H_2 decreases when H_1 is constant and, consequently, the value h_{sl} decreases from ϵ to 0.

Let us now set up the relationship between the indications h_{sl} of the gage and the actual value ϵ, and the difference $D_{sl} - D_{gag}$ which can be easily determined by measurement.

With the denotations used earlier it follows from Figure 4c that

$$h_{sl} = \varepsilon - h. \tag{11}$$

Let us now determine a number of the necessary intermediate relations.

$$NP = PO_3 + O_3O_1 + O_1N; \quad D_{gag} = 2r_{pr} + 2r_{dis}\sqrt{3}.$$

After expressing r_{dis} through ϵ from (3) we obtain

$$r_{pr} = \frac{1}{2}D_{gag} - \frac{\sqrt{3}}{2(2-\sqrt{3})}\varepsilon. \tag{12}$$

$$CF + FB = CO + OB; \quad CO = R_{sl} + h - R_{in}$$

After replacing R_{in} by $(r_{dis} - r_{pr})$ and using (3) and (12) we get

$$CO = \frac{1}{2}(D_{sl} - D_{gag}) - \frac{1}{2}\varepsilon + h. \tag{13}$$

From Δ OAO_3 we have

$$OA = r_{dis}\sin 30° = \frac{1}{2(2-\sqrt{3})}\varepsilon, \tag{14}$$

$$OA_3 = r_{dis}\cos 30^\circ = \frac{\sqrt{3}}{2(2-\sqrt{3})}\varepsilon. \quad (15)$$

From the right-angled triangle CAO_3 we obtain

$$(CO_3)^2 = (CO + OA)^2 + (AO_3)^2.$$

Using (13), (14), and (15) we substitute

$$(R_{sl} - r_{pr})^2 = \left[\frac{1}{2}(D_{sl} - D_{gag}) - \frac{1}{2}\varepsilon + h + \frac{1}{2(2-\sqrt{3})}\varepsilon\right]^2 + \left[\frac{\sqrt{3}}{2(2-\sqrt{3})}\varepsilon\right]^2.$$

The value of r_{pr} is found from (12)

$$\left[\frac{1}{2}(D_{sl} - D_{gag}) + \frac{\sqrt{3}}{2(2-\sqrt{3})}\varepsilon\right]^2 = \left[\frac{1}{2}(D_{sl} - D_{gag}) + h + \frac{\sqrt{3}-1}{2(2-\sqrt{3})}\varepsilon\right]^2 + \frac{3}{4(2-\sqrt{3})^2}\varepsilon^2.$$

After removing the brackets and combining similar terms we find

$$h^2 + h\left[(D_{sl} - D_{gag}) + \frac{\sqrt{3}-1}{2(2-\sqrt{3})}\varepsilon\right] - \frac{1}{2(2-\sqrt{3})}(D_{gag} - D_{sl})\varepsilon + \frac{1}{2(2-\sqrt{3})}\varepsilon^2 = 0.$$

On solving this equation with respect to $\underline{h}$, and substituting the value of $\underline{h}$ into (11), we finally obtain

$$h_{sl} = \frac{1}{2}(D_{sl} - D_{gag}) + \frac{3-\sqrt{3}}{2(2-\sqrt{3})}\varepsilon - \sqrt{\frac{1}{4}(D_{sl} - D_{gag})^2 + \frac{\sqrt{3}}{2(2-\sqrt{3})}(D_{sl} - D_{gag})\varepsilon}. \quad (16)$$

The root is taken with the negative sign, since h_{sl} cannot exceed ϵ.

The relation (16) is shown graphically in Fig. 5. For the construction of this curve various values of the difference $D_{sl} - D_{gag}$ were expressed as percentages of ϵ and used to calculate the corresponding values of h_{sl} in terms of ϵ. The graph enables an easy determination to be made of the relation between h_{sl} and ϵ for various definite conditions and, consequently, also of the value η of the theoretical measurement error expressed as a percentage.

The actual measurement error is somewhat smaller since the reading h_{sl} of the gage increases during the rotation of the workpiece by hand because of the minute particles of foreign matter which get into the sleeve, the presence on the surface of the components of minor defects, etc.

For the equal measured diameters and the values of pseudoroundness of five-crest pseudocircular components the moment when $h_{sl} = 0$ occurs is somewhat later than for the three-crest components, since for $D'_{gag} = D_{gag}$ and $\epsilon' = \epsilon$,

$$R'_{pr} = R_{pr} + 6.48\varepsilon \quad (17)$$

Therefore, in calculating the conditions for the correct gaging of the pseudoroundness in gage sleeves it is necessary to determine the size of the maximum possible error only for the three-crest case, which is the least favorable.

In practice the sleeves are more often used for making sure that the actual value does not exceed the allowance specified in the drawing for this element and not for measuring the pseudoroundness. The method of calculating the inspection conditions depends on whether the allowance for pseudoroundness is combined with the diameter tolerance or is specified separately [2 and 3].

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DEVICE FOR THE INSPECTION OF VERNIERS OF VERNIER CALIPERS

E. E. Rusiatinskii

The suggested device enables an efficient inspection to be made of vernier caliper verniers during their repair.

The device consists of the frame of a caliper to which a clamp holder is soldered for a small indicator gage with a gaging range of 2 mm. During inspection the slide is attached by means of a screw to the beam of the caliper being examined, in such a manner that the plunger of the indicator can make contact with the measuring surface of the jaw of the slide being inspected. In moving the slide with the vernier the coincidence of the graduations on the beam and the vernier is noted and compared with the readings of the indicator gage.

MEASURING DEVICES

S. A. Butskii

The existing devices for checking micrometers with a measuring range exceeding 100 mm, which consists of 2 plates with a stop for the screw, and are mounted on the micrometer frame or are made in the form of two hinged forks, are difficult to handle in fixing and cannot be fixed with an adequate rigidity.

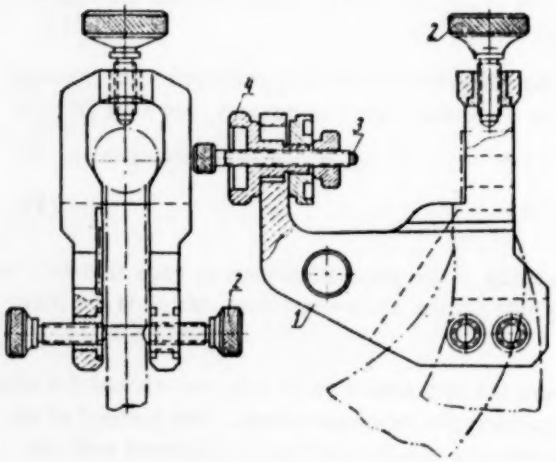

Fig. 1.

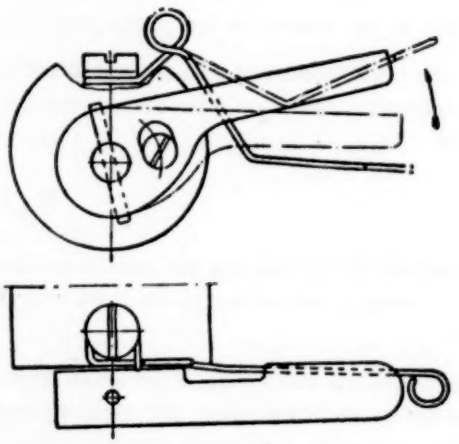

Fig. 2.

A more satisfactory device is used at the V. I. Lenin Kharkov Plant (Fig. 1); it consists of an aluminum body 1, three stationary clamping screws 2, and a sphere-pointed screw 3 with movable clamping nut 4. The micrometer is placed with its barrel in the v-groove of the device and secured by means of screws 2, after which the micrometer is checked by the conventional method with gage blocks.

In the IZM and Zeiss measuring machines the locking device cannot be operated in the extreme open-position of the spindle. This causes certain difficulties in working on the machine, and in the laboratories the locking devices are often removed and replaced by the type used in optical comparators, although this does not produce entirely satisfactory results.

A better locking device, used on the IZM-10 machine, consists of a spring made from 1-mm diameter steel wire, and M4 screw and M4 washer (Fig. 2).

ON THE DETERMINATION OF THE EFFECTIVE SCREW-THREAD DIAMETER

B. A. Kaliuta

In order to save time and to make the determination of the effective thread diameter easier, the Central Research Laboratory of the Buzuluk Engineering Plant uses marking on the ends of wooden boxes in which the wires are kept. The marking indicates the thread pitch for which the wires are used, the diameter and the value A (ascertained from the Table) which must be deducted from the dimension M. The boxes of wires are placed in a cupboard, arranged according to the thread pitch. Thus, the box with wires of the required diameter is found from the pitch marked on the box; for example,for checking a thread with a pitch of 2.5 mm, the box must be taken which is marked

2.5—1.441 2.158

where the first figures refer to the pitch, the second set of figures to the wire diameter and the last figures to the value A which must be deducted from the dimension M.

The boxes are marked by means of ordinary number dies; the impressions are subsequently filled with paint.

MEASUREMENTS OF MASS

EFFECT OF SPECIFIC LOAD ON THE VARIATION IN READING OF AN EQUAL-ARM BALANCE

G. A. Primak

The results of numerous checks on standard first-grade balances in the "Standards" Factory at Riga showed that 20, 200 and 1000 g balances easily passed the requirements of specifications 40-56 with respect to variation in reading, but that every 5 or 20 kg balance needed prolonged adjustment and checking.

Table 1 shows the characteristics of the first grade balances produced by the factory.

For comparison, it may be noted that the value of the specific load on the supporting knife-edge of a metrological balance, with a maximum load of 1 kg, amounts to 0.031 kg /mm at P = 0 and 0.081 kg /mm at $P = P_{max}$.

It can be seen from Table 1 that the specific load on the supporting knife-edge is considerable for balances V01-5 and V01-20, and this could be the cause of the variation in reading of these balances.

The variation in reading, at the first OTK checking at the factory, lay within the limits 0.1-0.4 of a scale division for balances with maximum loads of 20 and 200 g and 1 kg, and within 0.3-1.2, divisions for balances with maximum loads of 5 and 20 kg.

An investigation of the effect of specific load on variation in reading was carried out with a standard first grade balance No. 44, of maximum load 20 kg, which had been made in the Riga "Standards" factory in 1955. In order to obtain comparable results, the central and end knife-edges remained in a fixed position; a change in the value of the scale division was obtained by adjusting the position of the center of gravity of the beam.

TABLE 1

Type of balance	Maximum load in kg /mm	Length of supporting knife-edge in mm	Specific load in kg /mm		Composition of knife-edge and bearing
			without load	with maximum load	
V01-20	0.02	10	0.007	0.011	Agate-agate
V01-200	0.2	12	0.014	0.048	Agate-agate
V01-1	1	28	0.022	0.094	Agate-agate
V01-5	5	35	0.063	0.348	Steel-agate
V01-20	20	60	0.139	0.805	Steel-agate

A series of experiments was carried out, for each position of the regulating nut, to determine the variation in reading of the beam, without suspension and pans, for unloaded balances, and for balances with a 20 kg load on each pan.

The position of equilibrium was determined by four readings of the pointer deflection. The determination was carried out 11 times, the beam being brought to rest in between.

The variation in reading was expressed by:

$$\Delta_{max} = L_{max} - L_{min}.$$

The mean value of the variation of 11 determinations was calculated from the formula

$$\Delta_{av} = \frac{1}{n-1} \sum_{i=1}^{i=n-1} \left| \Delta_i \right|$$

where $\Delta_i = L_i - L_{i+1}$.

The value of Δ was expressed in scale divisions.

After the completion of each series of experiments, the value of a scale division was altered, and the next series of experiments was carried out. After several series of experiments, the working length of the central knife-edge was reduced and the experiments were repeated.

The greatest difficulty was experienced in decreasing this working length; if the knife-edge was removed from the beam, and then, by some means or other, its operating length (length of contact with the seating) was reduced, then the knife-edge did not take up precisely its original position when replaced, so that there was a change in the balance sensitively and the experimental results could not be compared.

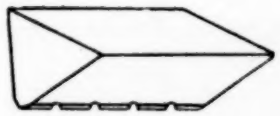

Fig. 1.

The following method was adopted for maintaining the state of the knife-edge unchanged, after altering its length. Before the final grinding of the knife-edge, grooves were cut in it in a few places with a honing machine (Fig. 1), and the lengths of these were measured with a travelling microscope. The finished knife-edge, with a cutting angle of 110°, was pressed into the beam. After the first six series of experiments had been completed, the beam was removed from the balance, and an individual section of the knife-edge was ground down to a depth of 0.15-0.20 mm. In this way the next series of experiments could be carried out with a decrease in the length of the knife-edge, but with absolutely no change in its position or in the quality of its finish.

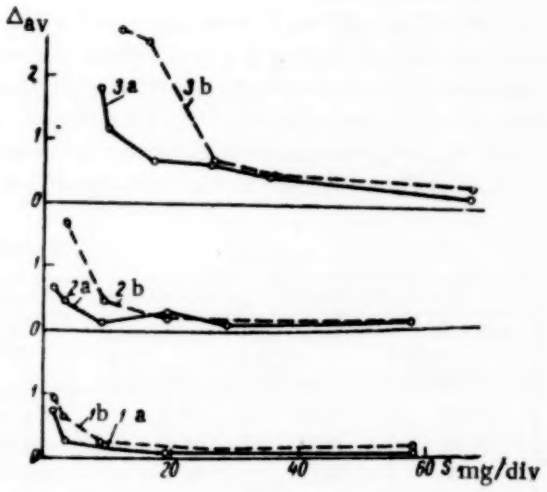

Fig. 2. Variation of Δ_{mean}.
1) Beam without suspensions and pans; 2) unloaded balance; 3) balance with 20 kg load on each pan.

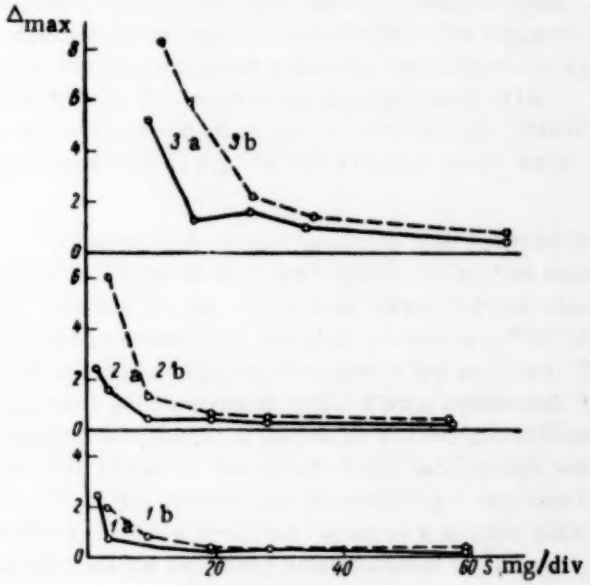

Fig. 3. Variation of Δ_{max}.
1) Beam without supports and pans; 2) unloaded balance; 3) balance with 20 kg load on each pan.

The lengths of the working part of the knife-edge were 51.95, 36.5 and 21.0 mm. Figures 2 and 3 show the change in the reading variation for knife-edges in length a) 51.95 mm and b) 21.0 mm. The specific loadings for these are shown in Table 2.

The graphs (Fig . 2 and 3) showed that increase in the specific load led to an increase in the reading variation of a standard balance. The most marked variation occurred with a sensitivity of 20-25 mg/division, which is the normal adjustment for a first grade balance with a maximum load of 20 kg. With a sensitivity of 40 mg/division, which corresponds to a second grade standard balance, the increase in variation shown was not so significant.

TABLE 2

Experiment	Specific load in kg /mm		
	Beam without pans and supports	Unloaded balance	Balance with 20 kg load
a	0.071	0.160	0.93
b	0.175	0.396	2.30

The reading variation Δ_{max} for a first grade standard balance is in accordance with specification requirements for a specific load up to 0.2 kg /mm (see Fig. 3, graphs 1b and 2a); with a specific load of about 0.4 kg /mm (2b) the reading variation exceeds the permissible value. It may be concluded from the above results that, with carbon steel knife edges, the maximum specific load for a first grade balance is 0.15-0.20 kg /mm.

In view of the technological difficulties in producing such a low specific load with heavily laden balances (5 and 20 kg), it is necessary to investigate and achieve a strengthening of the working parts of the contact pair "knife-edge, seating."

MECHANICAL MEASUREMENTS

ON THE PROBLEM OF REPRODUCTION AND MEASUREMENT OF VARIABLE FORCES

N. G. Tokar' and I. I. Mokeev

There is to date no satisfactory solution for the problem of analyzing, calibrating and checking of dynamometers under the influence of forces variable in time. The authors of this paper have developed methods and apparatus which make it possible to determine the frequency characteristics of a dynamometer while it is carrying out steady state harmonic oscillations and to measure the changes in these characteristics when objects of different mass are connected to the dynamometer. The apparatus (see diagram, Fig. 1) consists of a massive base 1, mounted on isolating supports 2. The dynamometer under test and the weight 4 connected to it are mounted on base 1.

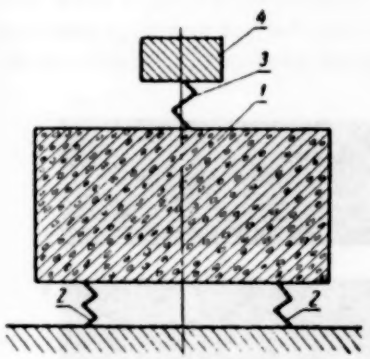

Fig. 1.

In the apparatus built by us the ratio of the mass of the base to the vibrating mass was within the limits of from 50 to 850, and the effect of the dynamic forces on the building floor was insignificant. The general view of the apparatus is shown in Fig. 2. The dynamometer is mounted on base 1. Above mass 2, which is screwed on to the shaft of the dynamometer, there is an electromagnet 3. An interrupter 4 is connected in the electric circuit of the latter.

The apparatus is so constructed that the gap between the vibrating mass and the electromagnet can be adjusted, and so that the interrupter can switch on the power supply always at a definite, predetermined point of the cycle (see curve 2 in Figs. 3a and 3b); by this means a stable regime of oscillations of a harmonic character is secured (curve 1 in Figs. 3a and 3b). Recording of the dynamometers vibrations was carried out by means of efficient strain-gage transducers, which were cemented on to the beam of the dynamometer. The signals from the transducer were recorded without interposing amplification on an MPO-2 oscillograph. Simultaneously the currents in the electromagnet coil were recorded (curves 2 in Fig. 3), and also time scale marks from the 50-cps line current (curves 3 in Fig. 3).

TABLE 1

Attached weight Q in kg	Experimental frequencies, f, cps		
	dynamometer DR-100	dynamometer DR-250	dynamometer DR-500
35.164	12.50	19.74	22.71
20.719	16.25	25.61	29.39
14.395	19.47	30.60	35.02
8.5242	—	39.40	—
8.5171	25.21	—	44.84
5.2992	31.75	49.31	—
2.7896	43.14	—	—
2.7646	—	66.19	—
1.9753	50.63	—	—

Objects studied were extension type beam dynamometers of the N. G. Tokar' system for applied forces of 100, 250 and 500 kg, which were tested in combination with nine exchangeable weights, whereby a sufficiently wide range of oscillation frequencies was provided. The frequency values given in Table 1 were determined by counting the number of cycles for a time interval (not less than 100 sec.), during which the oscillograph was on. This time interval was measured by a stop watch with an accuracy of 0.2 sec, whereby a relative accuracy of 0.2% for the frequency determination was secured. For each frequency determination at least three tests were run.

TABLE 2

Static calibration		Dynamic forces P_d, in kg						
		Frequencies in cps						
Average indications on dynamometer scale	Actual weight $P_{st.}$, in kg	12.50	16.25	19.47	25.21	31.75	43.14	50.63
45	10	9.94	9.91	9.88	9.80	9.67	9.40	9.16
67.4	15	14.9	14.9	14.8	14.7	14.5	14.1	13.7
89.7	20	19.9	19.8	19.8	19.6	19.3	18.8	18.3
112.1	25	24.9	24.8	24.7	24.5	24.2	23.5	22.9
135.5	30	29.9	29.8	29.7	29.4	29.0	28.2	27.5
157.7	35	34.9	34.7	34.6	34.3	33.9	32.9	32.1
180.4	40	39.8	39.7	39.5	39.2	38.7	37.6	36.7
203.0	45	44.8	44.6	44.5	44.1	43.5	42.3	41.3
225.7	50	49.7	49.6	49.4	49.0	48.4	47.0	45.8

TABLE 3

Static calibration		Dynamic forces P_d in kg					
		Frequencies, in cps					
Average indications on dynamometer scale	Actual weights $P_{st.}$, in kg	19.74	25.61	30 60	39.40	49.31	66.19
17.9	10	9 86	9.78	9.70	9.53	9.28	8 72
36.0	20	19.8	19.7	19.5	19.2	18.7	17.5
54.1	30	29.8	29 6	29.3	28.8	28.0	26.4
72.1	40	39.7	39.4	39.1	38.4	37.4	35.1
89.7	50	49.4	49.0	48 6	47.7	46.5	43.7
107.2	60	59.1	58.6	58.1	57.1	55.6	52.2
125.7	70	69 3	68.7	68.1	66.9	65.1	61.2
144.0	80	79.4	78.7	78.1	76.6	74.6	70.1
161.6	90	89.1	88.3	87.6	86.0	83.7	78.7
179.4	100	98.9	98.0	97.3	95.5	93.0	87.4
197.6	110	108.9	108.0	107.0	105.2	102.4	96.3
215.5	120	118.8	117.8	116.7	114.7	111.7	105.0
233.4	130	128.6	127.6	126.4	124.2	120.9	113.7

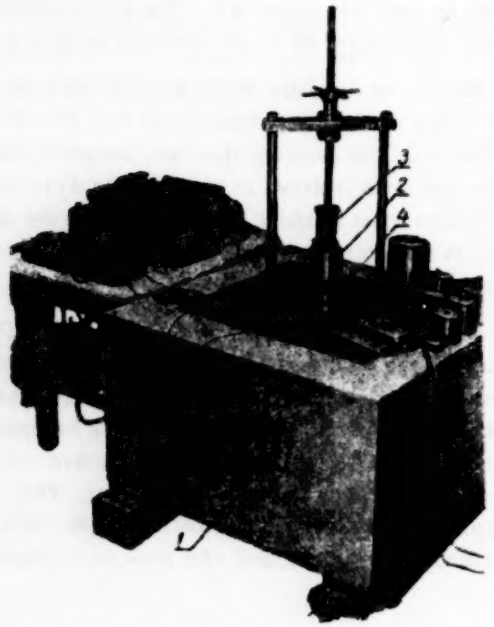

Fig. 2.

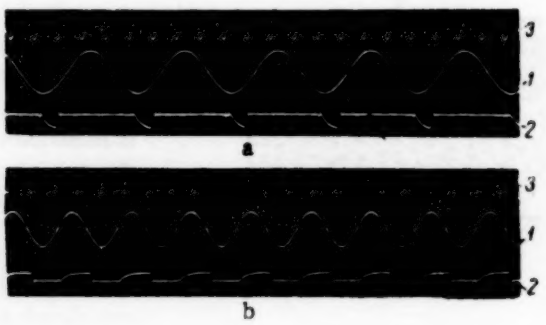

Fig. 3. Oscillograms of mechanical oscillations of an elastic system "dynamometer + mass."
a) Dynamometer for 100 kg frequency f = 12.5 cps;
b) dynamometer for 250 kg frequency f = 19.74 cps.

Amplitudes were determined by microscope measurements of the bending deformations of the dynamometers during oscillations. Graphic recording of these deformations was carried out by means of scratches on a celluloid tape which was run by a device developed earlier. Assuming on the basis of the obtained oscillograms that the oscillations are of a pure harmonic character, it is possible to calculate the actual maximum values of the dynamic forces by means of the formula

$$P_d = 4\pi^2 mAf^2,$$

where $m = \frac{Q}{g}$ = mass of attached piece; Q is its weight; g = 981.60 cm/sec^2 (for the place where the tests were conducted); f = the frequency of oscillations; A is their amplitude.

TABLE 4

Static calibration		Dynamic force P_d, in kg			
average indications on dynamometer scale	actual weight P_{st}, in kg	Frequencies in cps			
		22,71	29,39	35,02	44,84
33.7	25	24.6	24.3	23.9	23.2
67.3	50	49.1	48.4	47.8	46.4
101.1	75	73.7	72.8	71.8	69.7
134.4	100	98.0	96.7	95.4	92.6
168.2	125	122.7	121.1	119.4	115.9
201.9	150	147.3	145.3	143.3	139.2
235.6	175	171.8	169.6	167.3	162.4
269.2	200	196.3	193.8	191.1	185.6
303.2	225	221.1	218.2	215.3	209.0
336.6	250	245.5	242.3	239 0	232.0

Results of static and dynamic calibration tests of three dynamometers are presented in Tables 2, 3 and 4. They make it possible to estimate the effect of the dynamic character of a weight addition and prove that the developed apparatus and test procedure can be utilized for creation of standard instrumentation for reproduction and measurement of variable forces.

A TUNING FORK VIBRATION STAND

A. P. Pleshko and V. V. Perfil'ev

In various tests and especially in testsof high power motors, which often work under overload conditions, it is necessary to measure high-frequency vibrational accelerations which reach many hundreds of g's.

In view of the fact that existing vibration stands are able to produce only accelerations of not over several tens of g's, we have developed the special vibration stand described below for checking accelerometer transducers and examination of operational capabilities of small components and critical assemblies under the large vibrational accelerations to which they may be subjected.

To obtain vibrational overloads of 500 to 700 g's, there must be applied to the system an alternating force with an amplitude of several thousand kilograms. To produce such forces we have utilized the resonance properties of tuning forks having high magnification factors, the magnification factor being understood to be the ratio of the oscillation amplitude at resonance frequency to the bending deformation under static conditions under the influence of the same disturbing force.

A diagram of the newly developed vibration stand with 8 tuning forks is shown in Fig. 1.

The ends of both prongs of the tuning forks are provided with cut out portions in order to decrease the eddy-current losses. These ends are placed in magnetic fields of butt-end systems of excitation; the latter consist of two audio frequency coils w_1 and a coil of polarizing magnetization w_2, all mounted on an E-shaped core. When the polarization coil is supplied with dc (V = 24 v, I = 12 amp) from a GS-1500 generator, and the audio coils with ac from a 3C-2A audio oscillator, through amplifier TU-500, the prongs of the tuning forks are forced by the resultant magnetic field to vibrate at the frequency of the current in the audio coils. When resonance with the natural frequency of the tuning fork is achieved, the amplitude of the vibrations reaches a maximum. At the ends of the two tuning fork prongs two similar transducers or components to be tested are mounted in a symmetrical fashion.

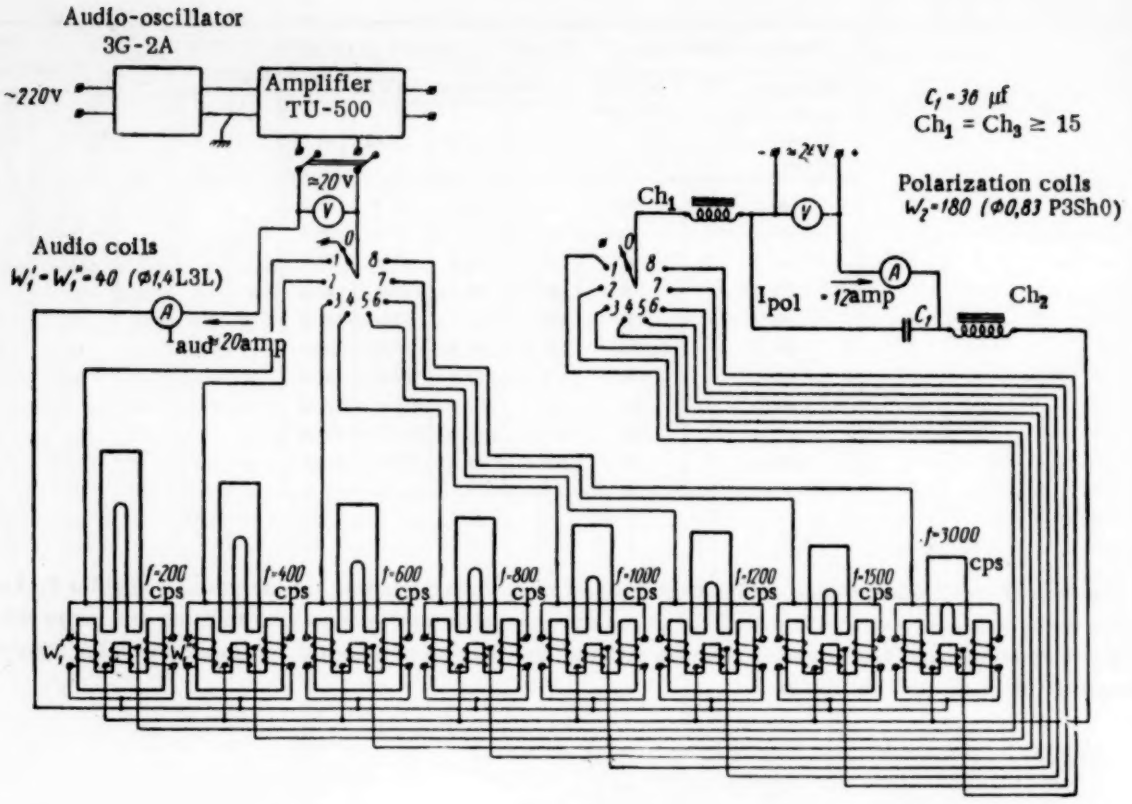

Fig. 1.

It should be noted that a butt-end magnetic system in comparison with a system located between the prongs, while having the disadvantage of a smaller gap provides considerably higher efficiency and a simpler and more convenient construction of mounting.*

When calculating the natural frequency of a tuning fork, the latter can be regarded as a symmetrical beam fixed at the midpoint. The natural frequency is determined by the formula for mechanical vibrations of such beams [2]:

$$f_c = \frac{1{,}875^2}{2\pi l^2}\sqrt{\frac{EI}{\rho F}}, \qquad (1)$$

where E is Youngs modulus of the tuning forks material, $I = \frac{bh^3}{12}$, the moment of inertia, ρ is the density of the fork material, F is the area of cross section, $\underline{l}$ is the length of a prong, $\underline{h}$ is the thickness of a prong and $\underline{b}$ is the width of a prong.

Given the permissible strains in the critical cross section σ_p, the permissible amplitudes of vibrations which are not to be surpassed during tests – A_p are determined by means of the formula

$$A_p = \frac{2}{3}\,\sigma\,\frac{l^2}{Eh}. \qquad (2)$$

*In view of the fact that with independent excitation of a tuning fork vibration stand a relative detuning is possible, which produces a change in amplitude of the reproduced vibrating acceleration, tuning fork vibration stands are built also using the well-known principle of self-excitation with feedback. – Editor.

The length of service life of a tuning fork is determined by how well it will stand up in vibrations, and that will depend upon the chosen dimensions as well as upon the material used.

It should be noted that a tuning fork made of S20 steel with a cross section of 120 x 80 mm was destroyed after 5 minutes work at a frequency of 400 cps, and an exactly similar tuning form made of 18KhNVA steel, which had been given a special heat treatment, was destroyed after 4 minutes. In both these cases the surfaces of the breaks showed the characteristic fatigue rings.

After a number of experiments, tuning forks of 250 x 80 mm cross section of S20 steel were made, which provided a total useful service time of more than 10 hours.

An assortment of such tuning forks with 8 fixed natural frequencies was mounted on a massive base plate supported on a special foundation.

The frequencies of these tuning forks are measured, when the oscillograms are analyzed by comparing the recorded frequencies with that of a standard frequency, or else by direct reading on the scale of the ZG-2A audio-frequency oscillator.

The measurement of the oscillation amplitudes is carried out by measuring the spread of the image of an index point by means of the micrometer arrangement in an OMS-3 universal microscope. The peak acceleration "a" of the vibration is determined by the formula:

$$a = 4\pi^2 f^2 A \frac{1}{g} \; [g]. \tag{3}$$

The total error in measurement of acceleration peaks is determined by the expression:

$$\delta = \left(\frac{\Delta(2A)}{2A} + 2 \frac{\Delta f}{f} \right), \tag{4}$$

where $\Delta 2A$ and Δf are the observational errors in measurement of the amplitudes and frequencies, respectively.

In the table below are presented data which are characteristic of the vibration stand's operation, and Fig. 2 is a general view of it.

TABLE

Consecutive No.	Tuning forks' length l in mm	Natl. frequency f_c in cps	Max. ampl. of osc. A in mm	Peak acceleration a in g's	Error in measurement of peak acceleration δ in %
1	300	200	1,2	270	<5
2	220	400	0,5	320	<5
3	170	600	0,3	450	<5
4	146	800	0,18	470	<5
5	128	1000	0,12	500	5,5
6	108	1200	0,10	550	7
7	100	1500	0,06	600	8
8	70	3000	0,02	720	17

The errors in measurement of the vibrational accelerations can be considerably decreased by using a microscope with higher resolution. It should be noted that when a condenser type micrometer is used, the error in amplitude measurement does not exceed 5%.

Fig. 2.

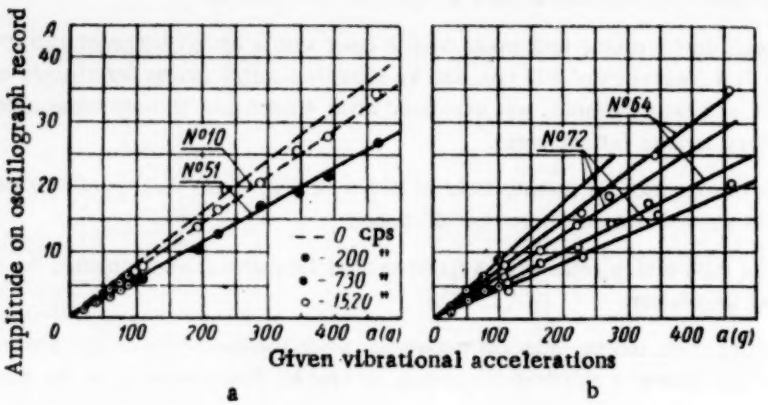

Fig. 3. a) Strain gage accelerometers; b) capacitive accelerometers.

During use of the stand, frequency characteristics of various types of accelerometers were obtained; in the course of this work it became apparent that it is necessary to carry out dynamical calibration of the transducers used, and a final choice of operational procedure was made. In Fig. 3 are presented calibration curves for two accelerometers of the capacitive type.

In the first type of accelerometers the vibrational accelerations under test produce deformation of a cylinder to which strain gages are pasted (f = 8.5 kc); in the second type the impressed accelerations produce a change in a gap (δ = 30 to 40 μ), between an immobile electrode and a membrane with a lump mass at the center (f = 3.5 kc). The change in the tangent of the inclination angle of the curves in Fig. 3b is proof of the nonlinearity of the frequency characteristics and its instability, which is caused by the variation in the degree of air damping in the small 30-40 μ gap. The difference between the dynamic and static characteristics for one of the strain-gage transducers indicates below-par assembly and, as a consequence, an incorrect static calibration. However, such a transducer after a dynamic calibration is entirely suitable for measurements.

In addition to this work on the tuning fork vibration stand, shaking tests at accelerations of 350 to 500 g's for various engineering purposes were made, and also durability and stability tests on various pressure transducers.

SUMMARY

The described tuning fork vibration stand provides the possibility of dynamic calibrations of accelerometer transducers and indicators, and also of checking the operational capabilities of components and their combinations of small weight under vibrational accelerations reaching 500 g's at fixed, predetermined frequencies.

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ELECTRICAL MEASUREMENTS

ELECTRONIC INTEGRATOR FOR MEASURING SMALL ELECTRICAL QUANTITIES

V. S. Volutskii

In many instances the limiting measuring accuracy of small quantities, for instance, weak currents, is determined by the internal noise of the equipment, especially amplifiers.

It has been shown in [1] that with a given internal equipment noise the error of measurement can be reduced by increasing the duration of measurement. In order to achieve this possibility we propose to apply the integration method quoted in [2].

The basic idea of this method is similar to making several measurements and taking the statistical mean of all the observations as the real value of the measured quantity. It can be shown [1] that the error decreases as the square root of the number of measurements made. This follows from the individual observation errors being subjected to the normal-distribution law and, with such a distribution, the dispersion is inversely proportional to $\sqrt{m}$, the square root of the number of measurements. The increase in the number of measurements, however, inevitably leads to an increase in the measuring time.

Electronic integrating device. Independently of [1] and considerably earlier we developed a simple electronic integrating device for measuring small electrical quantities.

Figure 1 shows its schematic. Where A is the measured object (a source of voltage), B_1 and B_2 two similar synchronously operating transducer contacts, Tp^1 and Tp^2 the input and output transformers of the ac amplifier, R_1 a resistance equal to that of the measured object, ∂_1 and ∂_2 detectors, n a dc microammeter, whose time constant T = RC is set by the values of resistances R_2, R_3 and R_4 and the capacity C.

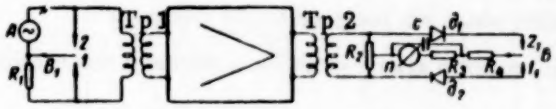


Fig. 1.

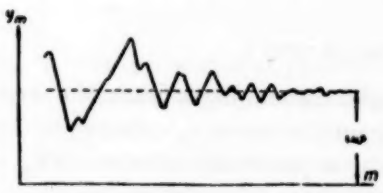


Fig. 2.

When contacts 1 and 1_1 are closed the amplifier input will receive signals. Providing the detector obeys the square law after smoothing by the RC filter the following current will flow in the circuit R_2, ∂_2, 1_1, R_4, R_3 and n, which forms one arm of the differential bridge,

$$\bar{I}_1 = k_1 (\bar{U}^2 + \bar{\xi}^2 + 2\overline{U\xi}), \qquad (1)$$

where U is the voltage of the measured signals, ξ is the voltage of the noise arising inside the amplifier (tube, thermal noise, etc), and k_1 is the coefficient depending on the equipment parameters.

Due to the absence of correlation between the signal and the noise the value of $\overline{U\xi}$ will tend to zero and, with a sufficiently good smoothing, it can be neglected.

In the following time interval when contacts 2 and 2_1 are closed only the equivalent resistance R_1 is connected to the amplifier input and no signals are fed to

the input, since the source of voltage is short-circuited. Therefore in the other bridge arm formed by R_2, ∂_1, 2_1, R_4, R_3 and n the following current will flow:

$$\overline{I_2} = k_2\,\overline{\xi^2}. \tag{2}$$

During a continuous working of the transducer the current through the bridge diagonal will be

$$\overline{I} = \overline{I_1} - \overline{I_2} = (k_1 - k_2)\,\overline{U^2}. \tag{3}$$

Thus, providing $k_1 = k_2$, the noise will be completely eliminated.*

The null method of measurement. Above circuit can be easily converted for a null method of measurement which does not require calibration of the amplifier since the latter only serves as a null indicator.

In order to measure by this method, the equivalent resistance R_1 (Fig. 1) is replaced by a source of calibrated signals, for instance, a standard signal generator or a noise generator. Otherwise the circuit is not changed.

1) The value of k_1 and k_2 depend in the main on the parameters of detectors d_1 and d_2 whose characteristics are selected to match. In addition the difference in the values of k_1 and k_2 can be compensated by means of resistance R_2 (Fig. 1).

When contacts 1 and 1_1 are closed the following current will flow in the corresponding arm of the bridge:

$$\overline{I_1} = k_1\,(\overline{U^2} + \overline{\xi^2} + 2\,\overline{U}\,\overline{\xi}). \tag{4}$$

When contacts 2 and 2_1 are closed the current in the other arm will be

$$\overline{I_2} = k_2\,(\overline{V^2} + \overline{\xi^2} + 2\,\overline{V}\,\overline{\xi}). \tag{5}$$

Terms $\overline{U}\,\overline{\xi}$ and $\overline{V}\,\overline{\xi}$ can be neglected since they tend to zero.

Then the bridge balance condition will be

$$k_1\,(\overline{U^2} + \overline{\xi^2}) = k_2\,(\overline{V^2} + \overline{\xi^2}). \tag{6}$$

If $k_1 = k_2$ the measured voltage will equal the calibrating voltage at balance.

$$\overline{U^2} = \overline{V^2}. \tag{6a}$$

Fluctuations of the mean noise values. The mean value of noise intensity $\overline{\xi}$ used in Eq. (2-6) is subject to fluctuations due to the statistical distribution of the noise pulses which are received by the integrator.

Let us note that the reading of the integrator output instrument n always gives the arithmetic mean value m of terms ξ_k.

$$Y_m = \frac{1}{m} \sum_{k=1}^{k=m} \xi_k. \tag{7}$$

where ξ_k is the random value of each noise pulse, m the number of pulses in time T.

The deviation of Y_m from its mean value $\overline{\xi}$, determined as the mathematical expectation of a random variable quantity, will characterize the fluctuations of the integrator output instrument n. When m is very large quantity Y_m will be almost equal to $\overline{\xi}$, and the indicator fluctuations will be practically eliminated: $\overline{Y}_m - \overline{\xi} \to 0$. With a decreased m the difference $Y_m - \overline{\xi}$ increases correspondingly and indicator fluctuations appear. The curve

* The values of k_1 and k_2 depend in the main on the parameters of detectors d_1 and d_2 whose characteristics are selected to match. In addition the difference in the values of k_1 and k_2 can be compensated by means of resistance R_2 (Fig. 1).

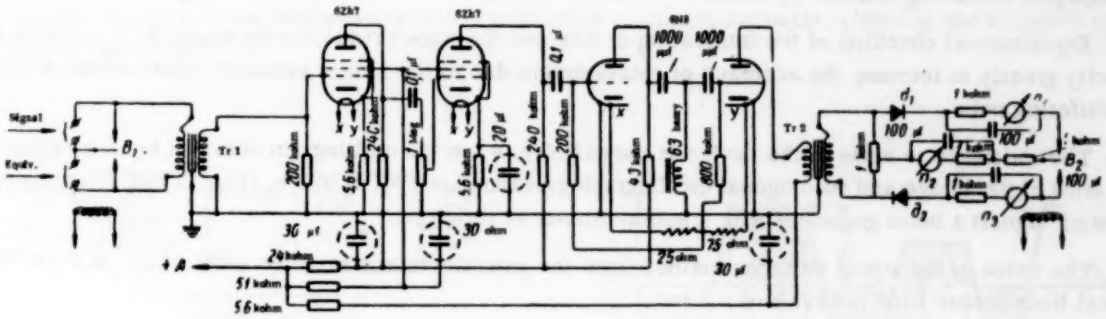
in Fig. 2 shows the relation between $Y_m - \bar{\xi}$ and $\underline{m}$.

With decreasing fluctuations.the Expressions (2-7) will be attained more accurately and the error of measurement will become smaller.*

For a higher accuracy of measurement, however, it is necessary to increase T, i.e., the duration of measurements.

It is shown in [3] that $Y_m - \bar{\xi}$ is inversely proportional to $\sqrt{m} = \sqrt{\Delta f T}$, where Δf is the amplifier bandwidth.

In practice when signals with a wide frequency spectrum are measured (radio noise, etc) it is possible to take the bandwidth Δf to be of the order of 10^6 cps and T of the order of 1 sec. In this case the accuracy of integration measurements can be raised 1000 times.



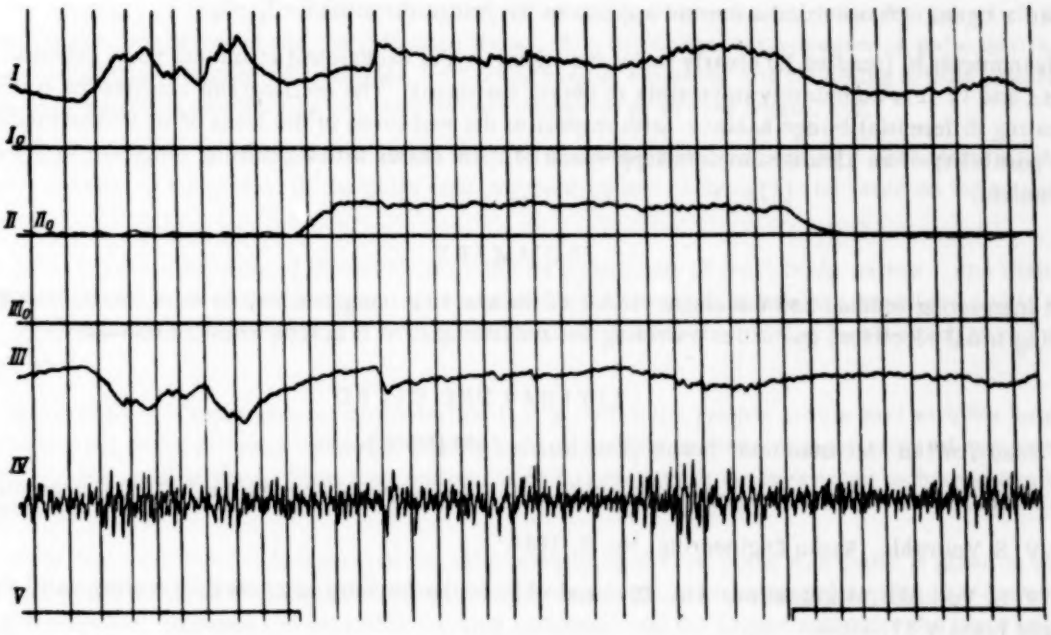


Fig. 4. I is the reading of galvanometer n_1 due to noise and signals in the bridge arm; II is the reading of galvanometer n_2 in the bridge diagonal; III is the reading of galvanometer n_3 due to noise in the bridge arm; I_0, II_0 and III(are the zero readings of galvanometers n_1, n_2 and n_3 respectively; IV is the reading of a galvanometer connected in the anode circuit of the last amplifier stage due to noise and signals before rectification and smoothing; V is the galvanometer reading for marking off the time the signal is being received; the instant the signal is received the reading is interrupted and it is restored again at the end of the signal transmission.

* Above reasoning applies to the case when threshold of the amplifier sensitivity i.e., the minimum value of a signal which the amplifier is capable of receiving is determined by the fluctuation noise.

Experimental check. The experimental circuit of an integrating device designed for measuring low-frequency fluctuation noise is shown in Fig. 3.

The circuit consists of an RC coupled amplifier with a transformer input and output, a voltage gain of 1.5 to $2 \cdot 10^6$ and a bandwidth of $\Delta f = 10^3$ cps. A choke-coil filter is connected between the third and fourth stages of the amplifier in order to eliminate hum (50 cps.)

The RC filter time constant can be changed between 0.1 and 1.0 sec by varying the appropriate resistors.

A polarized type RP-4 relay of contacts operating 80 to 100 times per second serve as synchronized switches at the input and output of the amplifier. Germanium detectors type DGTs-7 are used in the circuit. A dc microammeter type M-95 with a scale division between 10^{-7} and 10^{-8} amp serves as the output instrument, and photographic recording is made by means of a mirror oscillograph of the same sensitivity.

Experimental checking of the integrating device and the work carried out by means of it confirmed its capacity greatly to increase the accuracy of measurement due to the almost complete elimination of the effect of interfering noise.

The resistance to noise of the device is shown in Fig. 4 on the oscillogram obtained by connecting into both arms of the bridge and its diagonal oscillograph galvanometers n_1, n_2 and n_3 (Figs. 1 and 3) and using, as a source of signals, a noise generator with a potentiometer at its output.

The value of the signal voltage obtained from the potentiometer was of the order of 0.5 to 1 μv. The thick vertical lines denote time intervals of 0.1 sec.

Before the signal is transmitted, the galvanometers n_1 and n_3 are deflected in opposite directions by currents $\overline{I}_1$ and $\overline{I}_2$ in the arms of the bridge, due to the large variations of the internal noise of the amplifiers. Galvanometer n_2 in the diagonal of the bridge is only slightly affected by these noises varying about the zero reading (see the beginning of the oscillogram), since in the presence of noise alone (without a signal) $\overline{I}_1 = \overline{I}_2$.

When a signal is transmitted a current appears in the bridge diagonal $\overline{I} = \overline{I}_1 - \overline{I}_2$.

Galvanometer n_2 (reading II) clearly shows the signal on the background of intense noise, whereas from recordings I and IV it is completely impossible to obtain the signal. The oscillograms confirm the stability of the integrating differential bridge balance with respect to the variations in the level of its internal noise and prove the possibility of an almost complete suppression of these noises with a resulting increase in the accuracy of measurement.

SUMMARY

The integrating method and the above circuit of the electron integrator can be used for decreasing the error in measuring small electrical quantities providing the measuring time is correspondingly increased.

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MEASUREMENT OF PULSE-LEVEL RATIOS BY MEANS OF LAGGED VOLTAGE STABILIZERS

I. G. Gol'dreer and V. Iu. Den'gin

In designing electronic devices for measuring small nonelectric quantities one comes across difficulties connected with the instability of sensing elements (photocells, photomultipliers, etc) and amplifying and rectifying circuits. In order to increase the measuring accuracy of such devices it is usual to calibrate periodically the basic elements of the circuit. For this purpose, in addition to the measured signal, another reference signal is used. By this method, however, it is not always possible to attain high accuracy, since during the time elapsed after calibration, amounting to some tens of seconds, the parameters of circuit elements, affecting the accuracy of measurement, can change.

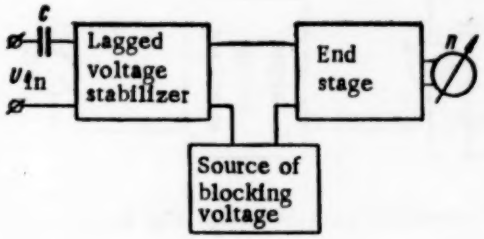


Fig. 1.

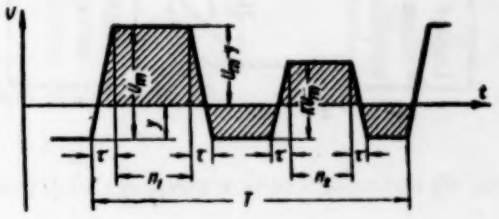


Fig. 2.

The accuracy of measurement is considerably increased in single-channel pulse devices which measure the ratio between the required and the reference signal. Single-channel ratio-measuring pulse devices can be used for most diverse purposes: for instance for finding various absorbing and reflecting effects, measuring color and color temperature, determining the luminescent properties of various bodies, etc.

In this article the authors generalize and develop a new method of designing a noncontact single-channel electronic measuring equipment of the pulse type proposed by one of them [1] and based on the utilization of thermistors.

Earlier [2] the measuring of the levels ratio of two pulses, (one of them being narrow and triangular in shape and the other wide and rectangular with considerably differing durations) was examined and it was found that by using the circuit shown in Fig. 1 it was possible to determine the ratio of levels which varied only over a narrow range.

On the basis of a more general consideration it is shown in the present article that with the help of the same circuit, but under different operating conditions it is possible to measure level ratios of two pulses of any duration over a wide band. Thus the application of this method in the measuring technique can be considerably extended.

Let us now examine the operation of the ratio-measuring device whose schematic is given in Fig. 1. Pulses with levels proportional to the quantities whose ratios are required to be measured are fed in sequence to the input of the device. Between the potential-dividing condenser and the lagged stabilizer the input voltage of a trapezoidal pulse has the shape shown in Fig. 2.

The lagged voltage stabilizer maintains the effective value of the output voltage constant (with a certain degree of accuracy) by means of the nonlinear resistance of the thermistor [3]. Moreover the shape of the output voltage reproduces exactly that of the input voltage due to the lagging of the stabilizer. Thus it may be considered that Fig. 2 also represents the output voltage of the stabilizer.

It is possible to convert the pulse voltage by means of the end stage in such a way that the indications of instrument n will be proportional to the required ratio k.

Various conditions of operation can be arranged for the end stage, for instance (see Fig. 2):

1. Amplitude measurements of:

a) the largest of the positive pulses ($U_m - y$),

b) negative pulses (y),

c) the sum of these pulses (U_m).

2. Measurement of the mean value of both positive or both negative pulses.

3. Measurement of the mean value of a part of the greater positive pulse, a part which lies above a certain level (the blocking voltage U_{blk}).

Each of these cases corresponds to a definite final stage circuit and a definite instrument scale for a given shape, duration and mark-space ratio of the pulses whose ratios are to be measured.

The schematic circuits for the three conditions described are given in Fig. 3a (condition 1a and 1b), Fig. 3b (condition 1c), Fig. 4 (condition 2), and Fig. 5 (condition 3).

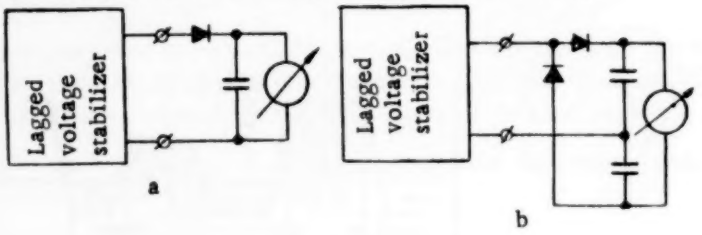


Fig. 3

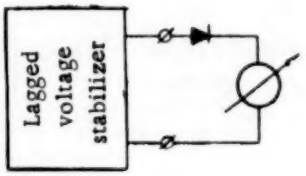


Fig. 4

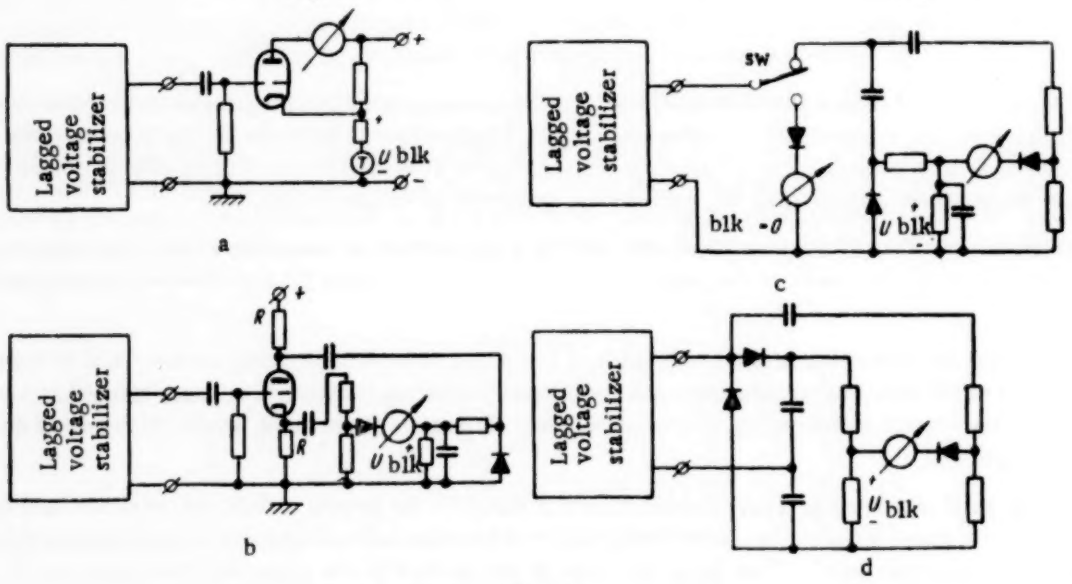


Fig. 5

Let us determine the shape of scales for different conditions of operation of the final stage.

In order to simplify the mathematical calculations the analysis will be made of trapezoidal pulses only (Fig. 2). It will, by the way, apply to triangular pulses as well.

In order to determine the shape of the ratio-measuring device scale it is necessary to find the relationship between the output voltage of the final stage and the level ratio of the measured input pulses.

The rise and fall of the trapezoidal pulses with respect to time follows a linear law, i.e., for the pulse front (Fig. 2) $U(t) = at$, moreover $U(o) = 0$ and $U(\tau) = U_m = a\tau$, where τ is the given pulse-time rise up to its maximum determined by the instrument's input circuit (for rectilinear pulses $\tau = 0$ and the expressions are considerably simplified). The instantaneous voltage value during the rise and fall of the pulse will be, for the first and second pulses, respectively,

$$U_1(t) = \frac{U_1(\tau)}{\tau} t, \quad \text{and} \quad U_2(t) = \frac{U_2(\tau)}{\tau} t. \tag{1}$$

Let us assume the required quantity to be the ratio of the level of the second (low) pulse to that of the first (high) pulse, i.e.,

$$k=\frac{U_2(\tau)}{U_1(\tau)}=\frac{U_2(t)}{U_1(t)}.$$

For simplicity of calculations let us assume τ to be the same for the first and second pulses. The time-scale displacement can be found from the instant at which the mean voltage equals zero at the input or output of the stabilizer.

The mean value of the stabilizer output voltage is represented by the integral (see Fig. 2):

$$\frac{1}{T}\int_0^T (U-y)\,dt=\frac{1}{T}\int_0^T U(t)dt-\frac{y}{T}\int_0^T dt=0$$

or

$$\frac{1}{T}\left[2\int_0^\tau U_1(t)dt+2\int_0^\tau U_2(t)dt+U_m n_1+kU_m n_2-y\,T\right]=0.$$

Considering that $U_2(t) = kU_1(t)$ and substituting $U_1(t)$ from (1) we shall obtain after integration the time axis displacement

$$y=U_m[k(\alpha_2+\alpha_0)+\alpha_1+\alpha_0], \tag{2}$$

where

$$\alpha_0=\frac{\tau}{T},\ \alpha_1=\frac{n_1}{T},\ \alpha_2=\frac{n_2}{T}.$$

For further calculations it is convenient to consider ratio y/U_m as a function of $\underline{k}$, i.e., to denote

$$\frac{y}{U_m}=Q(k), \tag{3}$$

where

$$Q(k)=k(\alpha_2+\alpha_0)+\alpha_1+\alpha_0.$$

The effective voltage at the output of the stabilizer is calculated from formula

$$U_{\text{eff}}=\sqrt{\frac{1}{T}\int_0^T (U-y)^2dt}$$

Taking this formula as the expression of the assumed pulse voltage we shall obtain the following relationship:

$$U^2_{\text{eff}}=\frac{1}{T}\left\{2\int_0^\tau (U_1-y)^2dt+(U_m-y)^2n_1+2\int_0^\tau (kU_1-y)^2dt+(kU_m-y)^2n^2\right\},$$

Whence we obtain for the final expression

$$U_{eff} = U_m \sqrt{a_1 + \frac{2}{3}a_0 + k^2\left(a_2 + \frac{2}{3}a_0\right) - Q^2}. \tag{4}$$

Since the lagged stabilizer maintains value U_{eff} constant we can deduce from here the relationship $U_m(k)$:

$$U_m(k) = \frac{U_{eff}}{A(k)}. \tag{5}$$

where

$$A(k) = \sqrt{a_1 + \frac{2}{3}a_0 + k^2\left(a_2 + \frac{2}{3}a_0\right) - Q^2}.$$

Now we can analyze the measuring conditions enumerated above.

In the first instance we shall determine the amplitude of the voltage U_{peak}:

a) $U_{peak} = U_m - y = U_m(1-Q) = U_{eff}\left(\frac{1-Q}{A}\right)$,

b) $U_{peak} = y = U_m Q = U_{eff}\frac{Q}{A}$,

c) $U_{peak} = U_m = U_{eff}\frac{1}{A}$.

Denoting $\frac{U_{peak}}{U_{eff}} = F(k)$ we obtain the following formulas, determining the shape of the instrument scales in this case, since U_{eff} is constant:

a) $F = \frac{1-Q}{A}$,

b) $F = \frac{Q}{A}$, (6)

c) $F = \frac{1}{A}$.

In this instance the final stage should consist of an ordinary peak voltmeter with an indicating instrument at the output. Its schematic is given in Fig. 3.

Figure 6 gives the data table for the three-peak voltage measuring conditions (a, b and c) for various shapes of pulses. It also shows the corresponding calibration curves $F = f(1/k)$.

In the two remaining operating conditions of the final stage the mean value of positive pulses is measured (for one period) and therefore it is necessary to calculate the shaded areas (Fig. 7 and 8).

It is peculiar to the second case (Fig. 7) that in calculating the mean value, either both or only one pulse need be taken into account (when the level of the lower pulse falls below the time axis, i.e., when $kU_m \leq y$). The mean voltage at instrument n is then determined by

$$U_{sr} = U_1 + \delta U_2,$$

where U_{Φ_1} and U_{Φ_2} are proportional to the shaded areas of the corresponding pulses and coefficient δ is

$$\delta=0 \text{ for } kU_m<y,$$
$$\delta=1 \text{ for } kU_m>y.$$

The general formula determining the shape of the instrument scale for the case when mean values of the positive (or negative) pulses are measured has the form

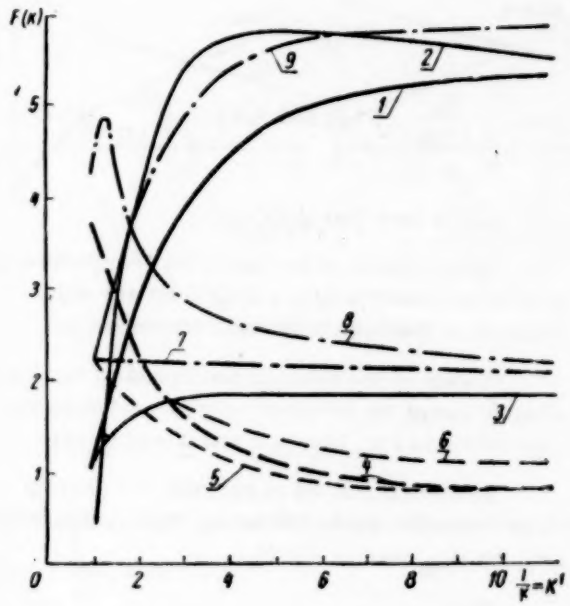
$$F=\frac{U_{av}}{U_{eff}}=\frac{1}{A}=\left\{[\alpha_1(1-Q)+\alpha_0(1-Q)^2]+\delta[\alpha_2(k-Q)+\frac{\alpha_0}{k}(k-Q)^2]\right\}. \quad (7)$$

The curves corresponding to this formula are shown in Fig. 9 (when $\beta_2 = 0$).

The final-stage circuit for this case is shown in Fig. 4.

In the third condition of operation the sensitivity of the instrument is increased by means of a blocking voltage which is chosen in such a manner that over the whole measuring range (see Fig. 8).

$$U_m-y>U_{blk}>kU_m-y. \quad (8)$$



U_{pk} –	a) U_m-y			b) y			c) U_m		
Curve No.	1	2	3	4	5	6	7	8	9
α_1	0	0	0,2	0,2	0	0,4	0,4	0,4	0
α_2	0,4	0,8	0,2	0,6	0,7	0,4	0,1	0,4	0,5
$\alpha_1+\alpha_2$	0,4	0,8	0,4	0,8	0,7	0,8	0,5	0,8	0,5
α_0	0,05			0,05			0,05		

$$F(k)=\frac{U_{pk}(k)}{U_{eff}}$$

Fig. 6.

The mean voltage measured by instrument n is proportional to the shaded area of the higher pulse

$$S=(x+n_1)\,h,$$

where

$$x=\tau\frac{h}{U_m}$$

and

$$h=U_m-y-U_{blk}=U_m\left(1-Q-\frac{U_{blk}}{U_m}\right).$$

The final formula for the instrument scale under condition of a blocking voltage has the form:

$$F=\frac{U_{av}}{U_{eff}}=\frac{1}{A}\left\{\alpha_1\left(1-Q-\frac{U_{blk}}{U_m}\right)+\right.$$
$$\left.+\alpha_0\left(1-Q-\frac{U_{blk}}{U_m}\right)^2\right\}. \quad (9)$$

The blocking voltage can be either constant or change with the measured value k, hence function $\frac{U_{blk}(k)}{U_m(k)}=\varphi(k)$ has a form which depends on the type of the blocking voltage.

In practice the following alternatives are convenient:

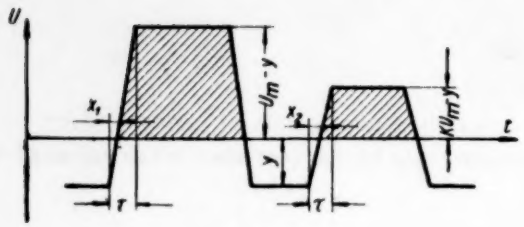


Fig. 7.

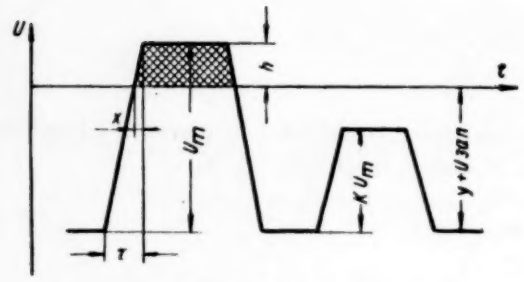
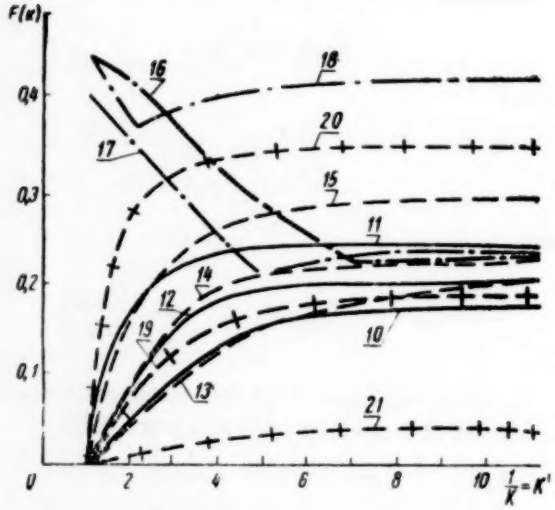


Fig. 8.



U_{blk}	$\beta_0 U_{eff}$			$\beta_1 y$			$\beta_2 = 0$			$\beta_3 U_m$		
Curve No	10	11	12	13	14	15	16	17	18	19	20	21
α_0	0	0,2	0	0	0	0,2	0	0	0,2	0	0,2	0
α_2	0,6	0,4	0,8	0,5	0,8	0,3	0,8	0,7	0,4	0,8	0,6	0,4
$\alpha_1+\alpha_2$	0,6	0,6	0,8	0,5	0,8	0,5	0,6	0,7	0,6	0,8	0,6	0,4
α_0	0,05			0,05			0,05			0,05		

$$F(k) = \frac{U_{av}(k)}{U_{eff}}$$

Fig. 9.

a) $U_{blk} = \text{const} = \beta_0 U_{eff}$,

b) $U_{eff} = \beta_1 y$,

c) $U_{eff} = \beta_2 (U_m - y)$,

d) $U_{blk} = \beta_3 U_m$.

Here U_{eff} and coefficients $\beta i (i = 0, 1, 2, 3)$ are constant, i.e., they are independent of k.

Quantities y, $(U_m - y)$ and U_m are functions of k [see (2) and (5)].

Above alternatives correspond to the end-stage schematic circuits shown in Fig. 5a, b, c, and d and calibrating curves shown in Fig. 9. for pulses of various durations and mark-space ratios.

The problem of choosing a blocking voltage is thus reduced to the selection of coefficients β on the basis of (8), for which purpose let us represent the inequality in the following form:

$$f_1(k) \leq \beta \leq f_2(k), \qquad (8a)$$

where

$$f_1(k) = \frac{U_m}{\left(\frac{U_{blk}}{\beta}\right)}(k - Q) \text{ and } f_2(k) = \frac{U_m}{\left(\frac{U_{blk}}{\beta}\right)}(1 - Q).$$

Let us note that $f_1(1) = f_2(1)$.

Investigation of the inequality (8a) permits one to plot relationships $f_1(k)$ and $f_2(k)$ for any pulse duration or mark-space ratio.

Curves of the function corresponding to above alternatives of the blocking voltage conditions are represented in Fig. 10a, b, c and d, respectively.

As an example let us examine the plotting of these curves for the first blocking voltage alternative, i.e., for $U_{blk} = \text{const} = \beta_0 U_{eff}$.

Here

$$f_1(k) = \frac{k - Q}{A} \quad \text{and} \quad f_2(k) = \frac{1 - Q}{A}.$$

It is possible to show that $f_1(k)$ attains a maximum at $k > 1$, whereas $f_2(k)$ is at a maximum at $k_2 < 1$.

Moreover by means of simple algebraic transformations and taking into account the obvious inequality $1 - \alpha_1 - \alpha_2 - 4\alpha_0 \geq 0$, it is possible to show that $f_1(0) < 0$ and $f_2(0) > 0$ and that $f_2(0) > f_2(1)$.

It will be seen from the curve of Fig. 10a that quantity β_0 which is common to the whole range

$0 \le k \le 1$ and which satisfies inequality (8a) is equal to the value of $f_1(1) = f_2(1)$.

i.e.,

$$\beta_0 = \frac{1-Q}{\sqrt{q(1-q)-\frac{2}{3}\alpha_0}},$$

where $q = Q(1) = \alpha_1 + \alpha_2 + 2\alpha_0$.

Thus the required quantity β_0 is controlled only by the shape of the pulses. For a narrower range of $\underline{k}$ it is possible to choose another value for β_0, thus gaining in sensitivity.

In fact choosing $\beta_0 = f_2(1)$ we shall obtain a larger value for U_{blk}, i.e., a smaller $\underline{h}$ for the same values of $\underline{k}$.

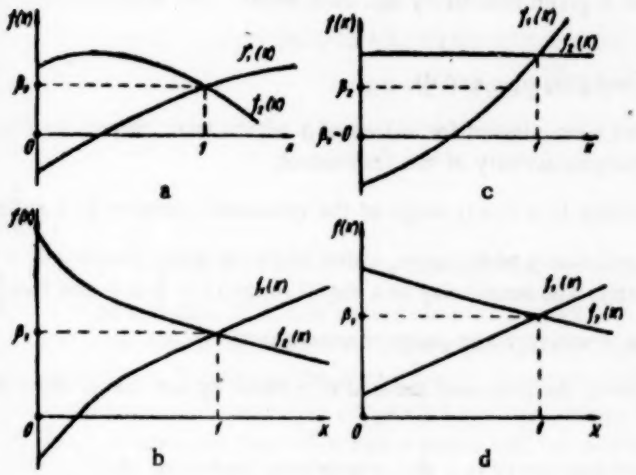


Fig. 10.

As was previously shown in (9), however

$$F = \frac{1}{A}[\alpha_1 h + \alpha_0 h^2]; \quad \frac{\Delta F}{F} = \frac{\alpha_1 + 2\alpha_0 h}{\alpha_1 + \alpha_0 h} \cdot \frac{\Delta h}{h} = (1 \div 2)\frac{\Delta h}{h}.$$

It is possible to show that for any $\underline{k}$ expression $\frac{d}{d\beta} \times \frac{\Delta F}{F} > 0$, i.e., that the relative change in the instrument reading increases with a rising β, in other words, with a rising sensitivity. This reasoning is also true for the other alternatives.

Formula (9), which determines the shape of the scale, has the form in the case of the first alternative:

$$F = \frac{1}{A}[\alpha_1(1-Q-\beta_0 A) + \alpha_0(1-Q-\beta_0 A)^2]. \quad (9a)$$

For the second alternative we have

$$f_1(k) = \frac{k}{Q} - 1 \quad \text{and} \quad f_2(k) = \frac{1}{Q} - 1,$$

quantitity β_1, common for the whole range of $0 \le k \le 1$, is equal to $\beta_1 = \frac{1-q}{q}$ (Fig. 10b) and formula (9) assumes the form

$$F = \frac{1}{A}\{\alpha_1[1-Q(1+\beta_1)] + \alpha_0[1-Q(1+\beta_1)^2]\}. \quad (9b)$$

For the third alternative

$$f_1(k) = \frac{k-Q}{1-Q} = 1 - \frac{1-k}{1-Q} \quad \text{and} \quad f_2(k) = 1,$$

and formula (9) takes the form

$$F = \frac{1}{A}\{\alpha_1(1-\beta_2)(1-Q) + \alpha_0(1-\beta_2)^2(1-Q)^2\}. \quad (9c)$$

Quantity β_2, common for the whole range of $0 \leq k \leq 1$, is equal to $\beta_2 = 1$ (Fig. 10c) but at the same time $F(k) \equiv 0$, i.e., measurements over the whole range are in this instance impossible.

It is peculiar to this alternative that the sensitivity and the range of measurements decrease with β_2, since it is necessary to choose a $\beta_2 < f_2(1)$.

The case of $\beta_2 = 0$ requires the simplest final stage circuit and completely satisfies the conditions of measuring the mean value of positive pulses (see above).

For the fourth alternative

$$f_1(k) = k - Q \quad \text{and} \quad f_2(k) = 1 - Q,$$

quantity β_3, common to the whole range of $0 \leq k \leq 1$, is equal to $\beta_3 = 1 - q$ (Fig. 10d) and formula (9) becomes:

$$F = \frac{1}{A}\{a_1(1-\beta_3-Q)+a_2(1-\beta_3-Q)^2\}.$$

Since the choice of quantity β determines both the measuring range and the sensitivity of the instrument, it is possible to find graphically the measuring range from a given sensitivity and vice versa. The description of this method requires special consideration.

Let us first examine curves plotted from (7), (8) and (9a, b, c and d).

Let us note that in Figs. 6 and 9 calibration curves were plotted for values of β which were chosen for the measuring range of $0 \leq k \leq 1$, i.e., not for the maximum sensitivity of the instrument.

Curves 2 and 20 correspond to a maximum sensitivity in a small range of the measured quantity $\underline{k}$ $\left(1 \leq \frac{1}{k} \leq 2\right)$, curves 1 and 13 correspond to medium sensitivity in a relatively wide range, curve 13 being more linear over a wide range; curves 16 and 17 correspond to a sufficient linearity and sensitivity in a small range $\left(1 \leq \frac{1}{k} \leq 6 \text{ and } 1 \leq \frac{1}{k} \leq 4\right)$.

The choice of a calibration curve depends on the sensitivity and range requirements.

Let us now examine the advantages and drawbacks of the proposed method of measuring the levels ratio of two periodically alternating pulses.

The use of a blocking voltage provides the highest sensitivity in a definite narrow measuring range; the final stage circuit in this instance, however, is relatively complicated and the accuracy of measurement depends on the stability of the blocking voltage. The value of the latter is to a certain extent affected by variations in the parameters of tubes and rectifiers.

The error in measuring the ratio in this instance can be estimated at 1.5 to 2% when a class 1 indicating instrument is used. The accuracy of measurement can be increased by periodic calibration of the device.

The measurement of the mean value provides sufficient sensitivity and linearity, the final stage circuit required is simple and reliable, but the measuring range is more limited than in the other cases (see curves in Fig. 9 at $\beta_2 = 0$), and the possibility of raising sensitivity by a better final-stage arrangement is lacking. The error of measurement is determined by that of the indicating instrument.

The measurement of the peak value provides a high sensitivity in a relatively wide measuring-range; moreover, the final stage circuit is relative simple. The accuracy of this method is only limited by that of the peak measuring output instrument.

In all these methods sensitivity can be increased over the measuring range by

1) raising the effective output voltage U_{eff} of the lagged stabilizer (by means of high-resistance thermistors),

2) an appropriate selection of the relation between the duration and the mark-space ratio of input pulses without changing their levels (see comparative curves in Figs. 6 and 9).

3) selecting appropriate final-stage operating conditions (the choice of the blocking voltage, of the rectifying circuit, etc).

The sensitivity of the instrument is determined by the derivative of the calibration curve.

The OKB of the Ministry of Geology and Preservation of the Natural Resources of the USSR developed on the basis of the described method a photoelectric photometer FF-1, designed to measure ratios in the range of $1 \leq \frac{1}{k} \leq 7$ with a possible 200% instability of input pulses. The instrument measures the amplitude of the higher pulse and with a sufficiently linear scale the error in measuring the ratio amounts to 1.5%.

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PECULIARITIES OF CALCULATING MOVING-COIL INSTRUMENTS WITH A FRAMED COIL

S. M. Pigin

The technique of calculating moving-coil instruments with a frameless coil has been described in [1].

The creation of tensile materials with a small residual aftereffect and the industrial production of negative-temperature-coefficient resistors (thermistors) provided the possibility of designing sensitive and highly accurate (class 0.1 to 0.5) instruments with a simple series temperature-compensating circuit (see Fig. circuit a), dispensing with the expensive, precision copper bobbins and complicated series-parallel circuits. In sensitive instruments, suspensions made of materials with a small residual aftereffect are used as elements for producing the required restoring moment.

For design purposes it is sufficient to examine three circuits (see figure): a) series circuit, b) same circuit, but with a graduated shunt, c) the same as the preceding circuit, but with multirange multiplier resistors.

It is assumed that the size of the coil frame is such that it satisfies the damping requirements and produces the degree of damping β_0.

The aim of the calculations is to determine the optimum circuit resistance values which would compensate for temperature variations and provide a very small damping. The basic calculation stages are practically the same as those described in [1].

The temperature error of a simple series circuit (circuit a) with a given voltage is

$$\gamma_u = \frac{r_o \alpha_o + r_f \alpha_f + r_t \alpha_t}{r_1} t = -(\alpha_M + \alpha_t) t = -\alpha_c t,$$

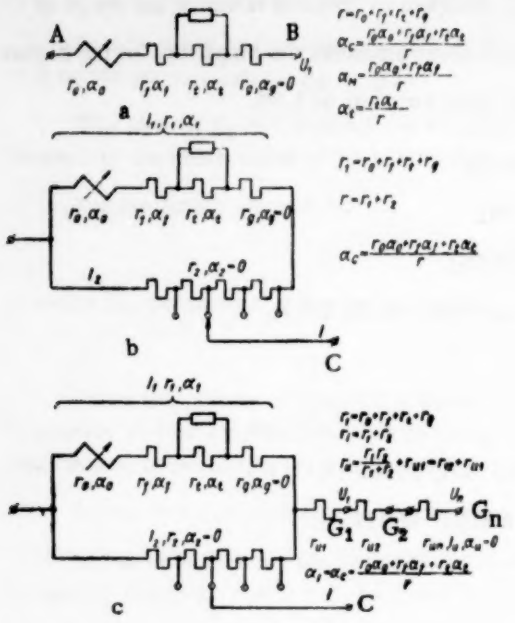
where α_M, α_t, α_c are the temperature coefficients of the frame with a suspension (springs) of a thermistor with a manganin shunt and all the circuits, and

$$r_1 = r_0 + r_f + r_t + r_g.$$

The temperature error of circuits b and c with the shunt r_2 with the given current is determined exactly as in [1], except that in this case the total resistance of the circuits is

$$r_1 = r_1 + r_2 = r_o + r_f + r_t + r_g + r_2.$$

Normally temperature coefficient α_2 of resistance r_2 is equal to zero. On the basis of (27) and (28) of [1] the temperature error of circuit c with a given voltage is approximately equal to:



Schematic of a moving-coil instrument; r_0 and α_0 are the resistance and the resistance temperature coefficient of the moving coil, r_f and α_f the same for torsion suspensions or springs, r_t and α_t the same for the thermistor shunted by manganin resistors, and r_g is a manganin building-out resistor.

$$\gamma_u \simeq -\frac{\beta_\kappa}{\beta_x} \cdot \frac{\alpha_1}{1+m}\, t$$

or more precisely

$$\gamma_u = -\left(1 + m\frac{r_{12}}{r_u}\right)\frac{\alpha_1\, t}{(1+m)+\alpha_1\, t} \simeq -\left(1+m\frac{r_{12}}{r_u}\right)\frac{\alpha_1\, t}{1+m},$$

where

$$m = \frac{r_2}{r_1} = \frac{I_1}{I_2},$$

r_u is the voltmeter resistance between terminals A and G, β_x and β_k are degrees of damping with open and shorted terminals A and G.

Considering that the temperature coefficient of branches $(r_1 + r_2)$ and r_1 are equal, respectively, to

$$\alpha_c = \frac{r_0\,\alpha_0 + r_f\,\alpha_f + r_t\,\alpha_t}{r_1 + r_2},$$

$$\alpha_1 = \frac{r_0\,\alpha_0 + r_f\,\alpha_f + r_t\,\alpha_t}{r_1} = \alpha_c\,\frac{r_1 + r_2}{r_1},$$

after transformation we obtain:

$$\gamma_u = \left[1 + \frac{m^2}{1+m}\;\frac{r_1}{r_u}\right]\gamma_I.$$

It is most difficult and at the same time most interesting to design millivoltmeters of a given class for the lowest possible voltage. If, for instance, one succeeds in designing an ammeter with a graded shunt for U millivolts it is only natural to incorporate in this instrument a millivoltmeter for U millivolts. This condition is fulfilled if the ammeter resistance is equal to that of the millivoltmeter. Thus, in this case $r_u = r_i = r_1 + r_2$.

For these conditions

$$\frac{r_1}{r_u} = \frac{r_1}{r_1 + r_2} = \frac{1}{1+m}$$

and the temperature error of the circuit is

$$\gamma_u = \left[1 + \left(\frac{m}{1+m}\right)^2\right]\gamma_I.$$

Thus, in a combined instrument, the temperature error when measuring voltage differs from the one obtained when measuring current. This difference increases with the rise in the total current I_u, the part of (I_1) which passes through the coil of the instrument. Hence in order to obtain temperature errors for an ammeter and a millivoltmeter, satisfactory for a given class, (they need not necessarily coincide) a small value of $\underline{m}$ will be required. In this method, similarly to other methods of temperature compensation, errors γ_u and γ_i will approach each other in magnitude when sufficiently large voltages are measured, i.e., when resistance r_u becomes large

compared with the constant resistance r_1 (or, which is the same thing, when the degrees of damping β_x and β_k practically coincide).

For all the possible cases of $0 < m \leq \infty$ the relation $\gamma_i < \gamma_u \leq 2\gamma_i$ will hold. Thus, under the stated conditions, the temperature error of the millivoltmeter circuit cannot be greater than twice the error of the ammeter circuit. Is it admissible to design an instrument with a value of γ_u approaching $2\gamma_i$? Is it necessary to strive for a zero-temperature error? The answer becomes clear from the following example. Let a measuring mechanism with a temperature error in the limits of γ_1 = +(0.05 to 0.15)%/10°C be assumed for design purposes. If a temperature error for an ammeter circuit of $\gamma_i = -0.1\%/10°C$ is obtained, the temperature error of the instrument for measuring current will be γ_i = (−0.05 to +0.05)%/10°C (see [1]). For the limiting value of $\gamma_u = 2\gamma_i$ the temperature error of the instrument for measuring voltage will be $\gamma_u = -(0.15$ to $0.05)\%/10°C$ which is completely permissible for a class 0.2 instrument. A satisfactory error for a class 0.1 instrument would be obtained with $\gamma_i = -0.07\%$.

It will be seen that the spread of the error γ_1 causes certain difficulties in selecting parameters for a combined instrument; these difficulties, however, can be overcome even with $\gamma_u = 2\gamma_i$. Moreover, neither for the ammeter nor for the millivoltmeter circuits is it necessary to have a zero-temperature error.

The calculations of the basic circuit parameters are considerably simplified if it is possible to select rationally the basic operation (C_1, T_0 and r_k) or design (ψ, I and W) parameters.

In order to ensure a minimum damping time the total degree of damping should be made to equal β = 0.9 to 1.0. Since the millivoltmeter according to circuit a (or an ammeter according to circuit b) can operate under short circuit conditions, it is desirable that the degree of damping of the circuit should be β_k = 0.1 to 0.2. Therefore, the total critical resistance should be $r_k = \beta_k r$.

In order to ensure the set damping time t_u, let us determine from the graph $\frac{t_u}{T_0} = f(\beta)$ [1] the free oscillations period T_0. Here $\beta = \beta_0 + \beta_k$.

The calculation of the moving-part elements is practically the same as described in [1].

The width and thickness of the coil winding is determined by the frame construction. The frame in turn is determined by the angle of deflection and the required gaps between the frame and the magnetic system with a minimum length of the magnetic airgap.

When the frame is completely filled the total cross section of the winding metal is $S_0 = k_0 ab$, where k_0 is the winding stacking factor.

The winding moment of inertia and its parameters are determined in the same manner as in [1].

The specific restoring moment is

$$W = \left(\frac{2\pi}{T_0}\right)^2 J,$$

where $J = J_k + J_0$ is the total moment of inertia.

The total flux linkage is $\pi\psi = C_J T_0 r_k$; since

$$r_k = \frac{\psi^2}{2\sqrt{JW}}, \quad \text{then} \quad \psi = \frac{2\pi\sqrt{JW}}{C_I T_0}$$

The spring or torsion suspension resistance r_f is found from the table for W.

If the resistance temperature coefficient of the measuring mechanism

$$\alpha_M = \frac{r_0 \alpha_0 + r_f \alpha_f}{r}$$

is found to be larger than permissible for the class of the instrument, compensation by a manganin resistor-shunted thermistor, with an equivalent temperature coefficient should be applied:

$$\alpha_t = \frac{r\alpha_c - r_0\alpha_0 - r_f\alpha_f}{r_t} = (\alpha_c - \alpha_M)\frac{r}{r_t} .$$

The weight of the moving coil winding is

$$G_o = k_u \gamma p\, qn,$$

where k_u is the winding weighting coefficient.

The weight of the moving part is

$$G = G_o + G_k .$$

The ratio of the restoring moment to the weight of the moving part is

$$A_w = \frac{W_1}{G} \cdot 2\,\frac{100}{l_o}$$

For instruments with vertical torsion suspension it is desirable to make this ratio not less than 4, in order to facilitate the required balance stabilization with respect to time.

Example 1. Instrument's design data.

B = 1600 gauss, S = 2.1 cm^2, P = 6.3 cm, J_k = 0.27 g·cm^2, G_k = 0.2 g, D = 1.75 cm, h = 1.75 cm, ψ_1 = BS = $= 3.36 \cdot 10^3$ maxwells, $\rho\gamma_{Cu} = 0.156 \cdot 10^5$ CGS,* $\rho\gamma_{Al} = 0.076 \cdot 10^5$ CGS.

A_1 = 4.13 cm^2, $\alpha = 85° = 1.48$ radians, $\beta = 0.9$, a = 0.27 cm, b = 0.05 cm, $S_0 = k_0 ab$.

Circuit a. Given: I = 0.1 ma, U = 10 mv, r = 100 ohms, $t_u \leq 6$ sec, class 0.2, $k_u = 1.2$, $k_0 = 0.65$.

1) We find $C_I = \frac{1}{\alpha} = \frac{0.1 \cdot 10^{-4}}{1.48} = 0.675 \cdot 10^{-5}$ CGS/rad ($0.675 \cdot 10^{-4}$ amp /rad).

2) We assume $\beta = \beta_0 + \beta_k = 1.0$.

3) Then $\frac{t_u}{T_0} = 1.05$ and $T_0 = 4.2$ (in order to ensure $t_u < 6$ sec).

4) The measuring-mechanism critical resistance is

$$r_k = \beta\ r = 0.1 \cdot 100 = 10 \text{ ohm}.$$

5) The winding moment of inertia is

$$J_0 = k_0\, abA = 0.118 \text{ g}\cdot\text{cm}^2 \simeq 0.12 \text{ g}\cdot\text{cm}^2\ (0.12 \cdot 10^{-7} \text{ kg}\cdot\text{m}^2).$$

6) The total moment of inertia is

$$J = J_k + J_0 = 0.39 \text{ g}\cdot\text{cm}^2\ (0.39 \cdot 10^{-7} \text{ kg}\cdot\text{m}^2).$$

7) The specific restoring moment is

$$W = \left(\frac{2\pi}{T_o}\right)^2 J = \left(\frac{2\pi}{4{,}2}\right)^2 \cdot 0{,}39 = 0{,}87\ \frac{\text{dyne}\cdot\text{cm}}{\text{rad}}\left(0{,}87 \cdot 10^{-5}\ \text{n}\cdot\text{m}\right).$$

8) The required flux linkage is

*Units of the cgs system.

$$\psi = \frac{2\pi\sqrt{JW}}{C_I T_o} = \frac{2\pi\sqrt{0{,}39 \cdot 0{,}87}}{0{,}675 \cdot 10^{-5} \cdot 4{,}2} = 1{,}29 \cdot 10^5 \text{ maxwell } (1.29 \cdot 10^{-3} \text{ weber}).$$

9) The actual value of the critical resistance will be

$$r_\kappa = \frac{\psi^2}{2\sqrt{JW}} = \frac{1{,}29^2 \cdot 10^{10}}{2\sqrt{0{,}39 \cdot 0{,}87}} = 14{,}3 \cdot 10^9 \text{ CGS} = 14 \text{ ohm},$$

and the degree of damping

$$\beta_\kappa = \frac{r_\kappa}{r} = \frac{14}{100} = 0{,}14,$$

which is sufficiently near the assumed value.

10) The number of turns in the winding is

$$n = \frac{\psi}{\psi_1} = \frac{1{,}29 \cdot 10^5}{3{,}36 \cdot 10^3} = 38{,}5 \text{ turns}.$$

11) The wire cross section is

$$q = \frac{I_o}{n A_x} = 0{,}0232 \cdot 10^{-2} \text{ cm}^2.$$

The nearest gauge value is $q = 0.0227 \cdot 10^{-2}$ cm², d = 0.17 mm.

12) The coil resistance is

$$r_o = \frac{\varrho p n}{q} = \frac{0{,}028 \cdot 6{,}3 \cdot 10^{-2} \cdot 38{,}5}{0{,}0227} = 3 \text{ ohm}.$$

13) In order to obtain the required restoring torque let us use torsion suspensions 25 mm long made of a platinum alloy:

$$\varrho = 0{,}3 \frac{\text{ohm} \cdot \text{mm}^2}{\text{m}} \qquad \alpha_f = 0{,}9\%/10°\text{C}.$$

14) From tables the torque of the torsion suspension at 90° and 100 mm length will be (in mg · cm)

$$W_1 = W \frac{25}{2 \cdot 100} \cdot 1{,}6 = 0{,}87 \frac{25}{2 \cdot 100} \cdot 1{,}6 = 0{,}18 \frac{\text{mg} \cdot \text{cm}}{90°/100 \text{ mm}}.$$

15) The resistance of 50 mm of such a torsion suspension is $r_f = 18$ ohms.

16) The temperature coefficient of the measuring-mechanism circuit equals

$$\alpha_u = \frac{r_o \alpha_o + r_f \alpha_f}{r} = \frac{3 \cdot 4 + 18 \cdot 0{,}9}{100} = 0{,}28\%/10°\text{C}.$$

With a temperature error of the measuring mechanism of $\gamma_1 = +0.1 \pm 0.05\%/10°C$ the corresponding α_M value of γ_2 is at the limit permissible for class 0.2 instruments.

17) If under the same conditions beryllium-bronze suspension is used, r_f will become equal to 3.9 ohms at $\alpha_f = 1\%/10°C$.

Then
$$\alpha_M = \frac{3 \cdot 4 + 3{,}9 \cdot 1}{100} = 0{,}16\%/10°C,$$

which is completely acceptable for class 0.2.

18) If platinum suspension is used a thermistor with the following temperature coefficient will be required (assuming $\alpha_C = -\gamma_2 = +0.10\%/10°C$ is permissible)

$$\alpha_t = \frac{r\,\alpha_c - r_0\,\alpha_0 - r_f\alpha_f}{r_t} = \frac{100 \cdot 0.1 - 3 \cdot 4 - 18 \cdot 0{,}9}{5} = -3.7\%/10°C$$

and the temperature error of the instrument will be

$$\gamma_M = \gamma_1 + \gamma_2 = \pm 0.05\%/10°C.$$

19) The weight of the winding is

$$G_0 = \kappa_a\ \gamma pnq = 1{,}2 \cdot 2{,}7 \cdot 6{,}3 \cdot 38{,}5 \cdot 0{,}0227 \cdot 10^{-2} = 0{,}18\ \text{g}.$$

20) The total weight of the moving part is

$$G = G_\kappa + G_0 = 0{,}2 + 0{,}18 = 0{,}38\ \text{g}.$$

21) The ratio of the restoring torque to the weight is

$$A_w = \frac{W_1}{G} \cdot \frac{2 \cdot 100}{l_0} = \frac{0{,}18 \cdot 2 \cdot 100}{0.38 \cdot 25} = 3{,}8.$$

Circuit b. This circuit is easily obtainable from circuit a (by short-circuiting terminals A and B of circuit a).

22) The minimum value of the branch is $r_1 = r_0 + r_f$, hence, the maximum value of the parameter is

$$m = \frac{r_2}{r_1} = \frac{r - (r_0 + r_f)}{r_0 + r_f} = \frac{r}{r_0 + r_f} - 1.$$

23) The minimum current I that such an ammeter with a graded shunt is capable of measuring is

$$I = \frac{1+m}{m} I_1 = \frac{r}{r_2} I_1 = \frac{U_a}{r_2},$$

hence, resistance

$$r_2 = r \frac{I_1}{I} = \frac{U_a}{I},$$

where U_a is the minimum measured voltage in circuit a.

If platinum suspension is used in this instance $r_1 = r_0 + r_f = 3 + 18 = 21$ ohms or with a margin of safety $r_1 = 25$ and $r_2 = 75$ ohms.

Hence,

$$I = \frac{r}{r_2} I_1 = \frac{100}{75} \cdot 0{,}1 = 0{,}133 \text{ ma (nearest I = 0.15 ma).}$$

With beryllium suspension ($r_1 \simeq 10$ ohms)

$$I = \frac{r}{r_2} I_1 = \frac{100}{90} \cdot 0{,}1 = 0{,}11 \text{ ma (nearest I = 0.12 ma).}$$

The calculation of the remaining steps of the shunt are not given since they have no theoretical significance.

Circuit c. The difference between this circuit and circuit a and b consists in the rise of the temperature error to

$$\gamma_u = \left[1 + \left(\frac{m}{1+m}\right)^2\right] \gamma_t.$$

Since the value of m and, hence, those of r_1, r_2, r_{12} and r_u are known from the previous example, it is easy to calculate the millivoltmeter temperature error. It is possible, however, to do the reverse: knowing all the millivoltmeter circuit elements it is possible to find a temperature error γ_t which would make γ_u satisfy the given class of instrument. This will require the return to circuit a and an improvement in its temperature compensation.

Example 2. Using the data obtained in the previous example we can obtain a millivoltmeter with a current consumption of I = 0.15 ma and

24) $$r_u = \frac{U_a}{I} = \frac{10}{0{,}15} = 66{,}7 \text{ ohm;}$$

25) $$r_2 = \frac{U_a}{I} = \frac{10}{0{,}15} = 66{,}7 \text{ ohm;}$$

26) $$r_1 = r - r_2 = 100 - 66{,}7 = 33{,}3 \text{ ohm;}$$

27) $$\gamma_u = \left[1 + \frac{m^2}{1+m} \cdot \frac{r_1}{r_u}\right] \gamma_t = \frac{5}{3}(-0{,}1) = -0{,}17\%/10^\circ\text{C.}$$

Above examples did not aim at giving the most advantageous alternatives; they were only meant to illustrate the course of calculations for certain given operational parameters. If the design damping time had not to exceed 3 sec (in order to ensure 4 sec) it would result in an almost doubled restoring torque and number of turns at the same weight of the moving part. As the result of the increased coil resistance the required thermistor unit temperature coefficient would have also increased, and the rise in the critical resistance would require a more careful consideration of damping.

SUMMARY

1. The combination of modern materials for suspensions (for instance, platinum-silver alloys) with thermistor temperature compensation provides a very sensitive and high-class (0.1 to 0.5) moving-coil instrument design.

2. The calculation of combined multirange instruments (of the millivolt ampere-voltmeter type) can be reduced to the calculation of a simple-series millivoltmeter circuit with subsequent specification of the combined instrument circuit details.

3. Class 0.1 multirange combined instruments require a careful selection of measuring mechanisms by their temperature error and its spread.

LITERATURE CITED

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ELASTIC AFTEREFFECT IN BRONZE SUSPENSIONS OF ELECTRICAL MEASURING INSTRUMENTS

Z. A. Timofeeva

The development and construction of electrical measuring instruments with torsion suspension is still being carried out without due calculation of the suspension parameters or an analysis of their operating conditions. When selecting and applying torsion suspensions, it is necessary to know in addition to their strength and the restoring torque, also the stresses in the suspensions and the extent to which they fail to return to zero (their elastic aftereffect) under given tensions.

Investigations carried out at the "Vibrator" plant have established certain regulaties in the behavior of suspensions providing the possibility of determining stresses arising in them and the expected deviation from their return to zero at these stresses with an error permissible in preliminary instrument calculations.

1. A suspension in an electrical measuring instrument is always subjected to a certain normal tension σ_H, whose value depends on the stretching it received on assembly.

When the moving part of the instrument is rotated there arise in the suspension certain tangential stresses τ, whose maximum value is attained in the middle of the long sides of the suspension and can be determined from formula

$$\tau_{max} = \frac{hG}{l}\alpha, \qquad (1)$$

where h is the thickness of the suspension, G is the modulus of rigidity, l is the length of the suspension, and α is the angle of rotation.

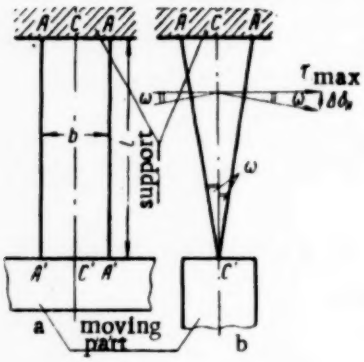


Fig. 1.

In order to deduce from the geometrical parameters of the suspension and from its elastic properties an analytical expression of the relationship between the deviation of the instrument's return to zero and angle α through which it has been rotated, let us examine the circuits shown in Fig 1a and 1b.

In the untwisted condition (Fig. 1a) all the suspension fibers are parallel to each other and cross section are at right angles to them. After a rotation through angle α (in the circuit of Fig. 1b through 90°) fiber CC' remains in the same position since it coincides with the axis of rotation and the extreme fibers (the boundaries of the suspension) are bent along a helix, obtaining an increment Δl. As a first approximation, this increment can be determined from the triangle ACC' (Fig. 1b). The suspension cross sections will change their shape during torsion and assume the form of special figures, which will be at an angle distinct from $\pi/2$ to the fiber CC', but perpendicular to the outside suspensions fibers AA'. At the points lying on the fiber CC' the cross sections form angles ω with the perpendiculars to the fiber at those points. For the cross section with the largest displacement, angle ω can be determined from the geometrical parameters of the suspension as

$$\operatorname{tg}\omega = \frac{b}{2l}, \qquad (2)$$

where b is the width of the suspension.

Tangential stresses have their maximum values at points near the axis of rotation and they are perpendicular to the axis.

Vector τ_{max} can be resolved into two components by projecting it in the direction of the outside fiber and in a direction perpendicular to it.

Let us denote the τ_{max} component in the direction of the outside fiber as $\Delta\sigma_H$ then:

$$\Delta\sigma_H = \tau_{max} \sin \omega. \tag{3}$$

Angle ω changes according to the length of the elongation from zero to a certain maximum value determined by the geometry of the suspension. Investigation of this question is outside the scope of the approximate theory and will not be discussed here.

In fact $\Delta\sigma_H$ is the normal stress increment which arises in the suspension when it is turned through angle α and which together with stress σ_H, provided by the initial tensioning of the suspension, causes the elastic strain in the suspension fibers. The elastic strains of the outside fibers prevent the moving-part of the instrument returning to its zero position.

Since angle ω is small, it is possible to assume that $\sin \omega \approx \tan \omega$ and then

$$\Delta\sigma_H = \frac{b\tau_{max}}{2l}. \tag{4}$$

Substituting the value of τ_{max} from (1) and (4) we obtain

$$\Delta\sigma_H = \frac{b h G}{2 l^2} \alpha. \tag{5}$$

Assuming that in twisting the suspension the elastic limit is not reached we can state that $\Delta i \approx \Delta\sigma_H$.

The amount by which the suspension fails to return to zero is also proportional to the strain, hence, denoting it by β we obtain

$$\beta = K_1 \frac{b h G}{2 l^2} \alpha, \tag{6}$$

where K_1 is the coefficient of proportionality.

It has been established experimentally that relation between the amount by which the suspension fails to return to zero and the time t during which the suspension remained twisted is

$$\beta \approx t^n. \tag{7}$$

Combining (6) and (7) we obtain a working formula in terms of all the required parameters from which the extent of the failure to return to zero can be calculated

$$\beta = K_2 \frac{b h G}{2 l^2} \alpha t^n. \tag{8}$$

The coefficient of proportionality K_2 and the index n in (8) must be determined experimentally.

Combining the modulus G/2 with the coefficient of proportionality we obtain, finally,

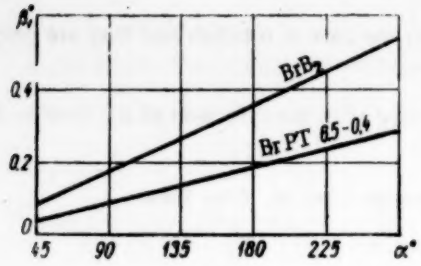


Fig. 2.

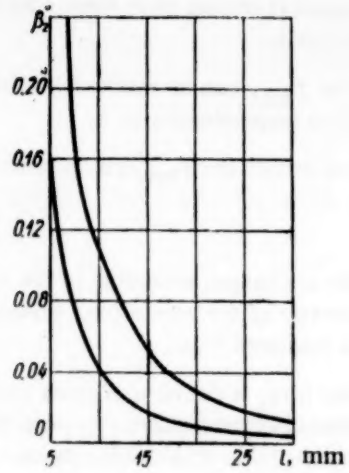


Fig. 3.

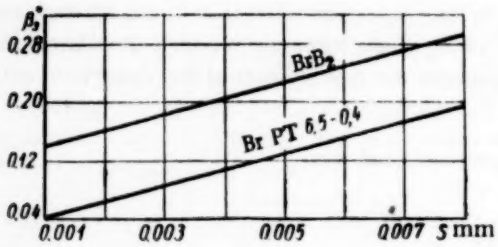


Fig. 4.

$$\beta = K\frac{bh}{l^2}\alpha t^n. \qquad (9)$$

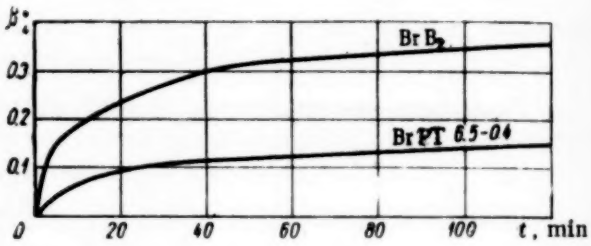


Fig. 5.

The design of instruments with suspensions of equal length is the most advantageous for obtaining the smallest failure to return to zero.

In case of suspensions of unequal length, calculations should be made for the shorter suspension since the stresses and strains arising in it will in the main, determine the extent of the failure of the moving part of the instrument to return to zero after twisting.

2. The investigation of the elastic aftereffect in the suspensions and the checking of formula (9) was carried out by means of a special equipment constructed in the "Vibrator" plant. The failure of suspensions to return to zero was determined with an error of ±0.01°.

The experimental work included the determination of the relation between the extent of the failure of the suspension to return to zero and length of the suspension l, its cross section bh, the angle of twist α and the time t during which it remained in the twisted position.

Suspensions were made of beryllium (BrB$_2$), Phosphor-tin (BrPT 6.5-0.4) and zinc-tin (BrZT 4-3) bronzes. The initial tension of the suspensions in all instances amounted to 25% of the breaking load.

The elastic properties of suspension made of BrPT 6.5-0.4 and BrZT 4-3 were found to be similar and therefore only test resultsobtained for phosphor-tin bronzes are given, since the latter suspensions are the most commonly used in industry.

Graphs in Figs. 2, 3, 4 and 5 show the empirically found relation between the extent of the failure to return to zero (elastic aftereffect) and the parameters enumerated above.

Figure 2 graph was obtained for beryllium and phosphor-tin suspensions of 0.0035 mm^2 cross section, 10 mm length and with a twisting time of 120 min. The graph shows the linear relationship between the extent of the failure to return to zero in degrees and angle of twist:

$$\beta_1 = A_1\alpha. \qquad (10)$$

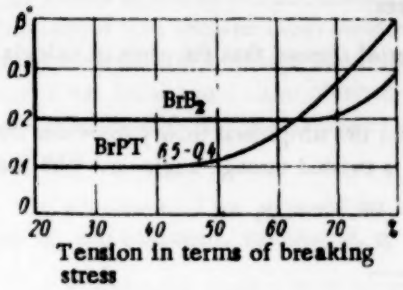


Fig. 6.

The slope A_1 of the curves shown in Fig. 2 is related to the elastic properties of the material and increases with the normal modulus of elasticity.

Figure 3 shows the relation between the extent of the failure to return to zero and the length of the suspension. This graph was plotted from results obtained with phosphor-tin suspensions twisted through 90° during 10 and 120 minutes. The relation is hyperbolic and is represented by expression

$$\beta_2 = \frac{A_2}{l^2}, \tag{11}$$

where A_2 is a function of the elastic properties of the material and the twisting time.

Figure 4 shows the linear relationship of the extent of the failure to return to zero and the cross sectional area of the suspension bh = S.

The linear relationship, obtained for normally used cross sections, cannot be extrapolated either for very small cross sections or for cross section which would produce residual strains when the suspension was twisted through angle α (in this case α = 90°).

Figure 4 shows a linear relationship represented by

$$\beta_3 = A_3 S + \beta_0. \tag{12}$$

The slope A_3 was found to be the same for different alloys. Quantity β_0 depends on the elastic properties of the material.

The relation of the extent of the failure to return to zero and the time of twisting, with all the other parameters remaining constant, is shown in Fig. 5. It is exponential and can be represented by

$$\beta_4 = A_4 t^k. \tag{13}$$

where A_4 and $\underline{k}$ can be obtained experimentally. By taking the logarithm of (13) we obtain a straight line equation in logarithmic coordinates.

$$\lg\beta_4 = \lg A_4 + k \lg t. \tag{13a}$$

The slope of the line gives the value of the index in (13), and the ordinate at t = 0, the logarithm of the coefficient of proportionality A_4 in (13).

Calculations of the values of A_4 and $\underline{k}$ for suspensions made of BrB_2 and BrPT 6.5-0.4 showed that $\underline{k}$ does not depend on the material used but is equal in both cases to 0.25.

Hence, the extent of the failure to return to zero is proportional to the fourth root of the time of twisting. Coefficient of proportionality A_4 characterizes the elastic properties and is different for the two materials.

It will be seen from the above that the experimental investigations of the properties and behavior of the suspensions lead to the same relationships as were obtained on the basis of the theory of elasticity and resistance of materials, i.e., to Expression (9) where coefficient K is a dimensional quantity $[K] = T^{-1/4}$ and is closely related to the modulus of rigidity

$$K = f(G, I). \tag{14}$$

The following values of K were obtained from the experimental data for the suspensions under investigation:

$$K_{BrB_2} = 23.5 \text{ and } K_{BrPT\ 6.5\text{-}0.4} = 10.5$$

providing the angles of twist and failure to return are expressed in degrees.

A check of the relations obtained and of (9) with a different material showed that the error in calculating the extent of the failure to return to zero amounts to ±15 to 20%.

3. The experimental confirmation of (9), which was obtained from the simplified theory, provides the means of calculating the total tension arising in the suspension when it is twisted through angle α. The maximum tension in the suspension can be determined from the expression

$$\sigma_{max}=\sqrt{(\sigma_н + \Delta\sigma_н)^2 + 4\tau^2_{max}}, \quad (15)$$

where σ_H is the tension caused by the initial stress of the suspension, $\Delta\sigma_H$ is the increment of the normal tension due to twisting, and τ_{max} is the maximum tangential tension.

Experiments have shown that with a given twist angle α the nonelastic strains begin to appear with different values of the initial tension σ_H. Figure 6 shows this relationship for suspensions made of BrB_2 and BrPT 6.5-0.4.

Technological factors exert a considerable influence on the behavior of suspensions. A preliminary calculation of the expected failure to return provides a measure of the extent to which the behavior of suspensions is influenced by soldering, skewing, or displacement of the suspensions when they are fixed in the instrument.

By comparing the observed extent of the failure to return with the calculated value, it is possible to discover and eliminate constructional and technological defects.

A BALLISTIC METHOD OF DETERMINING A HYSTERESIS CURVE BY MEANS OF SHORT CURRENT PULSES

E. Dzhakov, T. Stoichev and K. Stamenov

(Bulgaria)

The plotting of hysteresis curves of ferromagnetic materials with a large coercive force require a magnetic-field strength up to 5000 to 6000 amp/cm which is difficult to obtain, but can be obviated, if measurements are made by means of short current pulses.

The advantage of this method consists in the possibility of obtaining, by means of pulse excitation, currents of high density in the winding and, hence, a large magnetic field strength, many times greater than could have been obtained with a stationary field. On the other hand with the same magnetizing force it is possible to decrease considerably the size of the magnetizing winding. Due to these advantages it is possible with short-pulse excitation of the magnetic field to obtain the magnetization curve of ferromagnetic toroids or to use permeameters of a smaller size.

It is, however, impossible to use the conventional ballistic method of measurement with pulse excitation, since the galvanometer deflection lasts several seconds whereas the duration of the magnetic-field excitation is measured in fractions of a second. The induced current pulses in the measuring coil deflect the ballistic galvanometer in opposite direction when the field intensity is increasing or decreasing, thus making any measurements impossible.

The authors have investigated and developed a new ballistic method of obtaining a hysteresis curve by means of short current pulses by introducing into the circuit of the ballistic galvanometer an electronic time switch which connects the galvanometer only during either the increase or decrease of the magnetic field strength.

By means of this switch and ordinary heavy-current relays it is possible to obtain pulses for field excitation of a duration of 0.05 sec and over; moreover the ballistic galvanometer can according to the required conditions be connected either for the time when the current is rising or when it has reached its steady-state condition. In practice it was found more convenient to short-circuit the galvanometer instead of disconnecting it. Moreover it is possible to maintain the galvanometer damping practically constant by switching in appropriate resistances in series with it.

The schematic of the proposed set is given in Fig. 1 (where T is the sample under test with a magnetizing winding W_1 and measuring winding W_2 to which a ballistic galvanometer G is connected).

The magnetizing current from source 1 is connected by means of pushbutton A which operates a heavy-current relay P. The electronic switch PB is connected simultaneously, and after the lapse of a certain time operates relay P_2, which switches over the galvanometer, and relay P_1, which disconnects the magnetizing current (in the initial condition relays P_1 and P_2 are released). By means of switch K the galvanometer can be short-circuited either when the magnetizing current is increasing or when it is decreasing. This is achieved by selecting an appropriate operating current for the relays, so that at the end of the time delay, relay P_2 should operate first and then relay P_1. For measuring the maximum current value a peak-voltage-measuring tube voltmeter is used.

When a large ferromagnetic sample is being magnetized it is necessary to allow for the time the field takes to penetrate inside the sample and attain its steady-state condition. It is known [1] that this time can be obtained from the formula

$$\tau = \frac{\pi}{4} \mu \sigma a^2, \tag{1}$$

where μ is the permeability of the material in h/cm, σ is the conductivity in $ohm^{-1} \cdot cm^{-1}$, and $\underline{a}$ is half the thickness of the sample between its two parallel sides, in cm.

For substances of small permeability the penetration time is less than 0.05 sec with a thickness up to 2 cm. In determining the duration of the pulse the magnetic viscosity should also be taken into account; it is however difficult to express it by a numerical value. Ferromagnetic materials with a large permeabilities need not be measured by the pulse method.

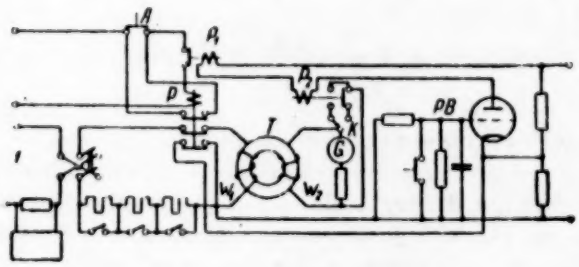


Fig. 1.

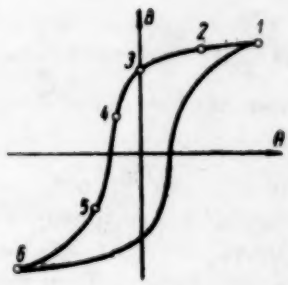


Fig. 2.

In order to check whether a stable state has been really reached with a given pulse duration it is necessary to make a few measurements with different pulse durations. If the values of flux density obtained are the same with different pulse duration, it can be safely assumed that the pulse is sufficiently long for the establishment of a steady-state field.

If it is assumed that the heat generated during short pulses is dissipated only in the windings, the relation between the pulse duration and the maximum permissible current density $\underline{j}$ in amp/mm² will be

$$j = \sqrt{\frac{4.18\, cd\Delta T}{\rho \tau}}, \tag{2}$$

where 4.18 joules/cal is the mechanical equivalent of heat, ΔT is the temperature difference between the winding and the surrounding medium, $\rho = 0.017$ ohms · mm²/m is the resistivity of copper, $c = 0.091$ cal/g · · degree is the specific heat of copper, and $d = 8.9$ g/cm³ is the density of copper.

Thus, for a pulse of a duration $\tau = 0.05$ sec, for instance, the current density can amount to some 2000 amp/mm². It is difficult to attain a larger current density by further decreasing the pulse duration, since conventional heavy-current relays will not deal with pulses shorter than 0.05 sec. Moreover the shortening of the pulse is limited in a ferromagnetic circuit by the time constant $\frac{L}{R}$ of the excitation circuit.

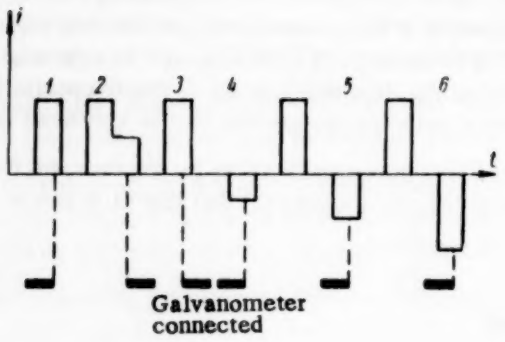


Fig. 3.

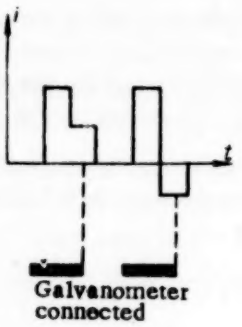


Fig. 4.

The high current density with pulse excitation provides the possibility of obtaining magnetization curves up to a magnetizing force of some 5000 amp/cm with toroids of relatively small sizes. The required internal radius of the sample is determined from formula

$$r = \frac{H_{max}}{50 K_1 K_2 j}, \qquad (3)$$

where H_{max} is the magnetizing force in amp/cm, K_1 is the copper stacking factor, K_2 is the stacking factor of the toroid internal-circle magnetizing winding, and j is the current density in amp/mm².

The hysteresis curve can be determined by means of current pulses according to the manner shown in Fig . 2 and 3.

The first pulse with the maximum current value should provide saturation given by point 1; the second pulse having reached the maximum value should immediately fall to the required value giving point 2; the third pulse measures remanent induction at point 3; the fourth flux density in the second quarter, given by point 4; the fifth flux density in the third quarter – point 5; and the sixth flux density at the saturation point 6. Obviously points of the type of 2, 4 and 5 can be taken in greater numbers by giving the pulses appropriate values.

In order to obtain a symmetrical hysteresis loop it is necessary before each of the pulses 1, 2 and 3 and before the first of the pulses of the type of 5 and 6 (Fig. 3) to pass through the magnetizing winding several maximum value pulses alternately changing in sign so that the last one of them is of the opposite polarity to pulses 1, 2, 3, 5 and 6.

It is possible, however, to use other pulse arrangements and other galvanometer connections. Thus, for instance, after demagnetizing the sample before each measurement it is possible to observe the general deflection of the galvanometer from both the pulses with opposite signs during the rise and the fall of the current to the required value (Fig. 4), i.e., to determine the flux density without calculating its difference. In this case, however, stepped pulses would have to be used, which would require a much more complicated electronic switch circuit.

The suggested method can also be used for measuring magnetic potential differences and magnetizing forces by means of a magnetic potentiometer and also for measurements with a fluxmeter. In the latter case if the induced pulse is obtained during a rise in the field strength, the resistance in the fluxmeter circuit should remain within permissible limits in order to avoid a second pulse when the measuring coil is switched over.

Finally, yet another advantage of the pulse method should be mentioned, the advantage of measuring at the maximum current, whereas in the stationary-field method the winding resistance can increase through heating which makes it difficult to stabilize the current.

Further development is being carried out in order to replace the existing electronic switch by germanium or thermionic diodes and to introduce a more complicated detecting electronic circuit with the object of obtaining a unidirectional current through the galvanometer, without the necessity of switching it off for a reversed current. Due to the nonlinearity of such components, however, the galvanometer deflection will depend not only on the amount of electricity which has flowed through it, but also on the amplitude and shape of the induced current pulse in the measuring winding. Moreover due to the presence of rectifying elements, interference from high-frequency oscillations is produced when the magnetizing current is connected or disconnected. In this connection the possibility of eliminating these difficulties and using current pulses from condenser discharges are being studied.

SUMMARY

The suggested new ballistic method of obtaining a hysteresis curve for materials with a small permeability has a number of advantages as compared with the conventional ballistic method. Magnetization by means of current pulses provides a current density in the magnetizing winding of the sample 400 to 500 times higher than normal and greatly simplifies the conditions of magnetization and measurement. Moreover, the sample does not heat up during measuring, which often occurs in the conventional ballistic method.

The hysteresis curves obtained by the new method for a steel with a coercive force of 24 amp/cm and for an aluminum-nickel alloy with a coercive force of 512 amp/cm coincided with the curves obtained by other methods.

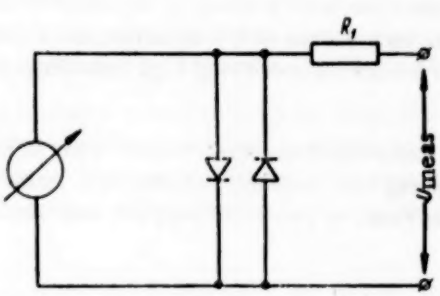
LITERATURE CITED

[1] I. I. Kifer and V. S. Pantiushin, Tests of Ferromagnetic Materials, Magnetic Measurements [in Russian (Gosenergoizdat, Moscow-Leningrad, 1955).

PROTECTING DEVICE FOR VOLTMETERS AND OSCILLOGRAPHS

L. V. Medvedev and L. N. Fitsner

The circuit shown on the attached drawing is used for the protection of voltmeters and loop oscillographs. This circuit includes as rectifiers nonlinear elements which have a very high resistance at low voltages and a small resistance at high voltages against which it is required to protect the instrument. Silicon diodes constitute such nonlinear elements.



At voltages up to 200-400 mv they pass practically no current; at higher voltages, however, they have a small resistance.

The circuit with silicon diodes shown on the attached drawing was tested experimentally. A microammeter M24, class 1 with a full scale of 100 μ amp and a resistance of 850 ohms was used as a measuring instrument. The connection of silicon diodes in a parallel with it did not change its readings up to a temperature of +70°C.

CONSTRUCTIONAL AND TECHNOLOGICAL PECULIARITIES OF ELECTROMETRIC INPUT CIRCUITS

V. M. Dmitrachenko

Equipment for monitoring and measuring radioactive emission under production and field conditions with temperatures ranging from −50 to +50°C and relative humidity up to 98% requires an especially careful over-all design but particularly so for its most important part, the input electrometric circuit.

At present the majority of instruments for measuring radioactive emission use ionization chambers as sensitive elements. For measuring the power of radioactive doses a high resistance is connected in series with the ionization chamber and the voltage across it is measured by means of an electrometer; for measuring radiation doses a condenser is connected in series with the ionization chamber, and the charge on the condenser is also measured by the electrometer.

In modern instruments, dc electronic-tube amplifiers are mainly used as electrometers. Investigations and practical experience of electrometric circuits have shown that in order to ensure the required precision it is necessary to fulfill the following basic requirements:

1. The resistors and capacitors of the electrometric input circuit must possess a high temperature and ageing stability and must be highly humidity-proof.

2. The mutual conductance and anode current of the electron tube (usually special electrometer tube) must be stable. The grid current must be small and stable.

3. The leakage resistance must be considerably larger than the corresponding circuit resistances. If, however, it is impossible to avoid a leakage effect, it must be made stable with time.

4. The parameters of all the input circuit components must be affected but little by radioactive emission. Possible effects on parameters must be taken into account in the design of the instrument.

5. The components of the input circuits and the ionization chamber must not emit, under the influence of temperature, time, or radioactive emission, any gases or vapors which could change the parameters of the ionization volume or the parameters of the input circuit components (for instance the leakage resistance).

Let us now examine some of the methods and procedures adopted for the fulfilment of these requirements.

1. The high-value KLM resistors used in the electrometers are unstable with time, have a large temperature coefficient and large resistance deviation (±20%). Heat-treatment of KLM resistors, however, by means of several temperature cycles from −40 to +60°C, sharply reduces their instability with time to limits which are determined by technical conditions. In order to adjust the value of KLM resistors it is recommended to heat them for 0.5 to 2 hours at a temperature of 150-200°C. This will decrease their resistance. By suitably choosing the temperature and duration of heating it is possible to obtain resistance values with a deviation not exceeding 3-5% (the accuracy of adjustment being limited by that of the instruments for measuring high resistors). This treatment of the KLM resistors is not detrimental to them.

The insulation resistance of the capacitor (for measuring the radiation dose) must be extremely high. This requirement is met by a polystyrene dielectric (Styroflex tape). Taking into account, however, the tendency of polystyrene to crack and strain it is necessary in specially important cases to check the capacity and insulation resistance of capacitors after their heat-treatment.

2. The parameters of mass-produced tubes used in electrometric circuits are not sufficiently stable. Experience has shown that ageing of tubes at their normal conditions of operation during 20-60 hours helps to stabilize their parameters. It should be noted that it is desirable to stabilize electrometer tube parameters by ageing at the plant which manufactures them. Unfortunately the technical specifications of a number of tubes (for instance 1Ē1P, 1Ē3P, and 6Zh1Zh) do not provide such ageing and their stability with time, therefore, is altogether insufficient.

3. It is especially difficult to ensure a high insulation resistance of lead-in circuits. In typical x-ray meters, dosage meters and other instruments, the effective insulation resistance of the most sensitive ranges is of the order of 10^{10} to 10^{12} ohms and the condenser used is of 3 to 100 $\mu\mu f$.

In order to make the leakage-insulation error not more than 1-5%, the total leakage-insulation resistance should be 20 to 100 times greater than the effective insulation resistances, i.e., it should be of the order of $2 \cdot 10^{12}$ to 10^{14} ohms. Since the instrument has several leakage paths, each path must have even a higher insulation resistance of some 10^{14}-10^{15} ohms. Leakage-insulation resistance of capacity-input instruments must be of the same order. Then the condenser will not have enough time to discharge appreciably through the leakage insulation resistance during testing.

The insulation resistance of insulators in individual dosage meters for small doses of 0.02 to 2 r must be even higher. In such dosage meters (for instance in the dosage meter KID-1) the capacity of the condenser is 2 to 5 $\mu\mu f$. Such a condenser should not discharge itself by more than 3% in 24 hours; i.e., its insulation resistance should be higher than 10^{16} ohms.

In typical electrometric circuits (see for instance the circuit of x-ray meter PMR-1, "Measurement Techniques" No. 1, 1956, pp. 89-90), leakages can occur in the following components: insulators supporting the internal electrode of the ionization chambers; the mounting plates of the switches for switching input resistors or condensers; the tube bulb which provides leakage paths from the anode and other electrodes to the control grid; circuit resistors (leakage across the surface) and capacitors (leakage across the surface and internally).

In designing electrometric circuits, two basic procedures are adopted: the use of a hermetically sealed electrometric unit, or the use of an open unit with part of the components hermetically sealed or with all of them open.

In the first instance the protection of the circuit components is simpler, which provides for less stringent requirements with respect to the insulation materials. In the second instance the highest quality insulation materials, have to be used and specially treated.

Usually the units are sealed hermetically by means of various sealing gaskets. As the result of many temperature and moisture variations, especially when the atmospheric pressure varies as well, moist air does penetrate into the unit. With temperature changes, condensation occurs inside the unit. Hence such hermetic sealing still requires considerable attention to be paid to the selection and design of current-carrying elements in the unit.

In an open unit it may be possible to protect some of the components from moisture; but protection against dust or dirt is practically impossible, and in time the insulation deteriorates considerably. It can be asserted, therefore, that the construction of open electrometric units is not expedient.

The newly produced Soviet insulation materials Ftoroplast-4 and Ftotoplast-3 are of the highest quality.* Over a very wide range of temperatures from −95 to +100°C (and up to +250°C for Ftoroplast-4) the insulation properties of these materials remain practically unchanged. Specific, bulk and surface resistances of the ftoroplasts exceed 10^{15} ohm · cm. Surfaces of insulating details made of Ftoroplast can be finished according to class 6 or 7 (GOST 2789-51), whereas details made of amber (until recently the only possible insulator for some electrometric components) must be finished according to class 11 or 12 and with carefully polished insulation surfaces.

Ftoroplast-4 details are made from billets in the shape of rods or slabs, or compressed (powder). Although Ftoroplast-4 is a thermoplastic material, its compression process is rather peculiar; the compression is done in cold dies with subsequent baking of compressed details in a thermostatically controlled oven at 350-380°C. The low viscosity of the powder and large shrinkage in baking prevent the use of Ftoroplast-4 for complicated details

* Ftoroplast-4 and Ftoroplast-3 are Russian trade names corresponding to "Kel-F" and "Teflon", respectively – Publisher's note.

of great precision. Ftoroplast-3 can be used for moulding in the way normally adopted for thermoplastic materials.

Unfortunately Ftoroplast details, especially flat ones, are subject to a change in dimensions and to shrinkage, and are not strong mechanically. Ftoroplast cannot be used, therefore, for making wafers for switches of normal construction.

The viscosity of Ftoroplasts, detrimental for certain types of load-carrying details, is advantageous for partition insulators which can be easily compressed and form a hermetic seal.

The use of Ftoroplast tape for making condensers with a very high insulation resistance which is preserved even in air with a relative humidity of 90-98% is of particular interest.

Details made of polymeric plastics such as polyethylene and polystyrene are less frequently used, although polyethylene has almost as good insulating properties as Ftoroplast at normal temperatures and humidity. An essential defect of polyethylene is its softness; yet polyethylene-insulated cables are widely used in electrometric circuits.

Despite the high insulating properties of polystyrene it should be used with caution, because it tends to crack. In use and storage, polystyrene develops microscopic surface cracks which lower considerably the surface resistance of the insulation. In order to decrease the tendency to crack, it is recommended to "fire" polystyrene details by heating them up to 85°C and then gradually cooling them off to 65°C. Details made of emulsion polystyrene have a smaller tendency to crack than those made of bulk material.

The most important defect of polystyrene and polyethylene is their low melting point which limits their use above 80°C.

Radio ceramics make an excellent constructional material for insulating details. Their great mechanical strength, very small moisture-absorbing properties, large bulk resistance, high temperature stability — all these properties make them indispensable in a number of instances.

Without special preparation, however, radio ceramics cannot be used in electrometric circuits. They have a relatively low surface insulation resistance at a medium relative humidity of air. In order to raise their surface resistance, ceramics should be treated with a silicon-organic lacquer, ceresin or paraffin wax.

Best results are obtained when silicon-organic lacquers are used, which form after drying a mechanically strong protective layer. Ceramic details covered with silicon-organic lacquers are easily cleaned with a solvent or pure alcohol.

Paraffin wax and ceresin are used for filling cavities in polystyrene and ceramic insulators with the object of decreasing their moisture absorption and also of raising their surface insulation resistance. The use of ceresin- and paraffin-wax coatings is limited by their low melting temperature, mechanical weakness and a tendency to accumulate dirt, which cannot be easily removed without removing the coating itself as well. In dust-protected or hermetically sealed units, however, paraffin and ceresin coating produces completely satisfactory results.

In selecting insulation materials for electrometric circuits, attention should be paid to the variable nature of the surface insulation resistance of tube-bulb glass, especially alkaline glass. The surface resistance of glass drops to hundredths of its original value with changes in temperature and air humidity. In a damp atmosphere, silicate hydrolysis reactions occur on the glass surface. The glass surface layer becomes saturated with silicate hydrolysis products, which are electrolytic.

With a relative air humidity of 0 to 20% the mean value of the specific surface resistance of glass lies in the limits of 10^{12}-10^{15} ohms. With a humidity of 30% the resistance drops to 0.5-0.3 of its value. In the range of relative humidity of 30 to 80% the resistance drops to 10^{-2} to 10^{-4} of its value. A rise in temperature at a constant humidity decreases the resistance to 0.5-0.3 of its value at 80% humidity and to 10^{-2} at 60% humidity. This relation between the insulation resistance and the temperature and humidity leads to the so-called false grid current.

Treatment of the tube bulb in boiling water (distilled or previously boiled) for 2-4 hours considerably increases the surface resistance due to the leaching of the glass surface. This treatment is particularly convenient when changing tubes in operation conditions. The treatment of the tube bulbs in silicon-organic compound vapors (for instance in dimethyldichlorosilane vapor) produces very good results, but makes tube replacement by the user

more difficult; it becomes necessary to supply the required quantity of treated spare tubes in appropriate packing or to supply the silicon-organic compounds, with instructions for treatment.

4. Electrometric instruments are usually subjected, in operation, to effects of x-ray and radioactive radiations.

The effect on insulation resistance of the value of the dose and duration of irradiation differs for different insulators, depending on the relation of effective factors. A detailed investigation of this phenomena and its consideration in designing instruments is of great importance.

5. A number of insulating materials exude when subjected to temperature cycles or natural ageing (especially condensed resins of the type of phenolaldehyde plastics), gases and moisture. In electrometric units which are not sealed hermetically, this phenomenon has no practical significance, in hermetically sealed units it can have a considerable effect on the operation of the ionization chamber and electrometric circuits.

In order to avoid this effect it is advisable not to use condensed-resin plastics, replacing them as far as possible by polymerized resins (of the type of polystyrene, polyethylene and Ftoroplast). Details made of condensed resins can be greatly improved by using the following moulding process: a preliminary high-frequency heating of the moulding powder, pressing for an optimum length of time with recompression for a better removal of gases and vapors, subsequent additional baking of moulded details at a temperature of the order of 120 to 150°C during 12 to 24 hours and ageing by several temperature cycles (from −40 to +60°C).

HIGH AND ULTRAHIGH-FREQUENCY MEASUREMENTS

TEMPERATURE CONTROL OF CRYSTAL ELEMENTS

V. F. Lubentsov

Various bridge temperature-control circuits [1, 2] are used for ensuring a constant temperature of crystal elements in standard crystal oscillators. In this instance the peculiarity of control consists in measuring or setting a temperature with an error of the order of 0.2 to 0.5°C and maintaining it at the given value with an error not exceeding 0.002 to 0.02°C.

A resistance thermometer is used as the basic measuring unit in the bridge circuit. The circuit (Fig. 1) is balanced at a set temperature of thermostat T. A change in this temperature produces across the bridge diagonal a voltage which is amplified by the dc amplifier Y. The output of the latter is connected to an electronic or electromechanical relay, which connects or disconnects the heater of thermostat R_H.

A more rational control circuit [3, 4] in which the measuring element is combined with the heater in the resistance thermometer is given in Fig. 2. This circuit under certain conditions provides a smooth temperature control, which eliminates heat waves and provides a simpler thermostat construction.

Power relations in the circuits under consideration. The measuring bridge circuit (Fig. 1), consisting of resistors R_1 and R_3 with a temperature coefficient α and resistors R_2 and R_4 constant with temperature, is balanced at the stable temperature t°_2 inside the thermostat and an ambient temperature t°_1.

Power P used for heating the thermostat can be determined from the relationship

$$P = P_M + P_H = AT^\circ, \tag{1}$$

where P_M and P_H are the powers supplied respectively to the bridge and the heater, A is the thermostat constant equal to the power required to raise the thermostat temperature by 1°C above that of the surrounding medium, and $T = t^\circ_2 - t^\circ_1$.

When the ambient temperature changes by ΔT° it is necessary to raise the power supplied to the heater, in order to maintain the temperature inside the thermostat at the same level with an error not exceeding Δt° by ΔP_H, as the result of which the new value of the established power P_1 will be

$$P_1 = P_M + P_H \pm \Delta P_H = A(T^\circ \pm \Delta T^\circ). \tag{2}$$

It can be shown [5] that when the temperature of the bridge changes by Δt° with respect to the balance temperature t°_2, there will appear in the diagonal resistance R_5 a current ΔI_∂ determined from equation

$$\Delta I_\partial = \frac{\alpha \Delta t^\circ}{4(m+1)} \sqrt{\frac{P_M}{R}} \tag{3}$$

which holds under the following conditions:

$$\alpha \Delta t^\circ \ll 1;\ R_1 = R_3 = (1 + \alpha \Delta t^\circ)R;\ R_2 = R_4 = R;$$

the amplifier internal resistance $R_0 = mR$; $R_5 = R$ is the condition for maximum power in the bridge diagonal.

Current ΔI_∂ increased by the amplifier must change current I_H to such an extent as to provide a change in the heating power of $\Delta P_H = \Delta I_H^2 R_H$. Hence, taking (1) and (2) into account we obtain:

$$\Delta I_H = \sqrt{\frac{A}{R_H}}\left(\sqrt{T^\circ \pm \Delta T^\circ} - \sqrt{T^\circ}\right). \qquad (4)$$

Power P_M dissipated in the bridge can be represented as a part of the total power used to heat the thermostat:

$$P_M = A(T^\circ \pm \Delta T^\circ)\, n,$$

where

$$n = \frac{P_M}{P_M + P_H \pm \Delta P_H}.$$

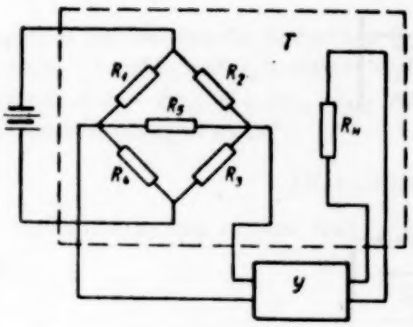


Fig. 1.

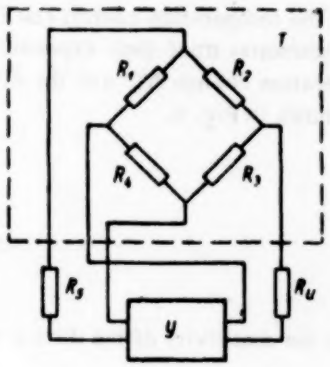


Fig. 2.

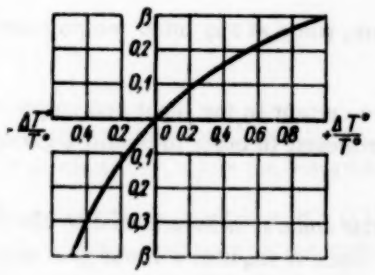


Fig. 3.

Taking (3) into consideration we obtain:

$$\Delta I_\partial = \frac{\alpha \Delta t^\circ}{4(m+1)} \sqrt{\frac{A}{R}\,(T^\circ \pm \Delta T^\circ)\, n}. \qquad (5)$$

Thus, the amplifier gain $K = \frac{\Delta I_H}{\Delta I_\partial}$ required for temperature control with an error of Δt° is equal to

$$K = \frac{4(m+1)}{\alpha \Delta t^\circ}\left[1 - \frac{1}{\sqrt{1 \pm \frac{\Delta T^\circ}{T^\circ}}}\right] \times \qquad (6)$$

$$\times \sqrt{\frac{R}{R_H}\left(1 + \frac{P_H}{P_M} \pm \frac{\Delta P_H}{P_M}\right)}.$$

The instrument's control coefficient Π according to (6) is represented by expression

$$\Pi = \frac{\Delta T^\circ}{\Delta t^\circ} = \qquad (7)$$

$$= \frac{K \alpha \Delta T^\circ}{4(m+1)\left[1 - \frac{1}{\sqrt{1 \pm \frac{\Delta T^\circ}{T^\circ}}}\right] \sqrt{\frac{R}{R_H}\left(1 + \frac{P_H}{P_M} + \frac{\Delta P_H}{P_M}\right)}}$$

Relationships for the circuit of Fig. 2 can be derived similarly:

$$P_M = AT^\circ. \qquad (8a)$$

The value of the power established after a change in the ambient temperature:

$$P_1 = P_M \pm \Delta P_M = A(T^\circ \pm \Delta T^\circ). \tag{8b}$$

The current in the bridge diagonal:

$$\Delta I_\partial = \frac{\alpha \Delta t^\circ}{4(m+1)} \sqrt{\frac{A}{R}(T^\circ \pm \Delta T^\circ)}. \tag{8c}$$

Variation of the current feeding the bridge:

$$\Delta I_M = \sqrt{\frac{A}{R}}\left(\sqrt{T^\circ \pm \Delta T^\circ} - \sqrt{T^\circ}\right). \tag{8d}$$

Gain:

$$K = \frac{4(m+1)}{\alpha \Delta t^\circ}\left[1 - \frac{1}{\sqrt{1 \pm \frac{\Delta T^\circ}{T^\circ}}}\right] \tag{8e}$$

Control coefficient:

$$\Pi = \frac{K \alpha \Delta T^\circ}{4(m+1)\left[1 - \frac{1}{\sqrt{1 \pm \frac{\Delta T^\circ}{T^\circ}}}\right]}. \tag{9}$$

From these relationships the following conclusions can be drawn.

a) The gain of the amplifier (with given values of α and Δt°) and the temperature control coefficient (with given values of α and K) do not depend on the degree of lagging of the thermostat since their expressions do not contain coefficient A, but are function of the ratio of the ambient temperature change ΔT° and the difference in temperatures T° inside and outside the thermostat. This relationship is shown in Fig. 3.

$$\left(\beta = 1 - \frac{1}{\sqrt{1 \pm \frac{\Delta T^\circ}{T^\circ}}}\right)$$

The nonlinearity of the curve (in Fig. 3) is explained by the rise in the sensitivity of the device with an increase in the temperature difference T° at a constant value of ΔT°.

The nonlinear relation between the gain and the temperature difference T° makes it difficult to maintain the temperature of the thermostat with a constant error within set limits.

The amplifier gain should be determined for the lowest temperature, since at any other temperature in the range the control error will be smaller.

b) The degree of thermostat lagging A determines the value of the current in the input and output circuits of the amplifier and hence the power required to be dissipated in the thermostat in order to obtain a given difference in temperatures inside and outside the thermostat.

c) The form of relationship of the first and second circuits is similar since it is determined by the form of function β; the second circuit, however, has an advantage over the first since it requires a lower gain amplifier

for the same control conditions. Moreover, the second circuit is simpler in construction since it provides a smooth control and it has no separate heating winding.

Instability of the thermostat temperature. Variations in the thermostat temperature are due to a number of reasons, the most important ones being the following:

1. Variation in the temperature of the surrounding media. The degree to which these variations affect the changes of the thermostat temperature Δt° is determined by the basic parameter of the system called the control coefficient II. From expressions (7) and (9) it follows that

$$\Delta t^\circ = \frac{\Delta T^\circ}{\Pi}. \tag{10}$$

2. The instability of the bridge resistors due to ageing, changes in the mechanical stress of the resistance wires, and changes in the insulation resistances which shunt the bridge resistors.

These phenomena lead to a change in the established relations between the bridge arms and hence to a change of the balance temperature of the bridge.

Let us assume that the bridge was first balanced with resistors R_1 and R_3 (wound with wire with a temperature coefficient α) and R_2 and R_4 (constant with temperature). As the result of ageing these resistors change, assuming new values of $R_1 + \Delta R_1$, $R_3 + \Delta R_3$, $R_2 + \Delta R_2$ and $R_4 + \Delta R_4$. In order to re-establish balance the temperature of the bridge must be changed by Δt°_c:

$$(R_1+\Delta R_1)(R_3+\Delta R_3)(1+\alpha\Delta t^\circ_c)^2=(R_2+\Delta R_2)(R_4+\Delta R_4).$$

Hence, taking into account that $R_1 \cdot R_3 = R_2 \cdot R_4$ we have

$$\Delta t^\circ_c = \frac{1}{\alpha}\left[\sqrt{\frac{\left(1+\frac{\Delta R_2}{R_2}\right)\left(1+\frac{\Delta R_4}{R_4}\right)}{\left(1+\frac{\Delta R_1}{R_1}\right)\left(1+\frac{\Delta R_3}{R_3}\right)}}-1\right]. \tag{11}$$

Since $$\frac{\Delta R_1}{R_1}=\frac{\Delta R_3}{R_3};\quad \frac{\Delta R_2}{R_2}=\frac{\Delta R_4}{R_4}.$$

then $$\Delta t^\circ_c = \frac{1}{\alpha}\left[\frac{1+\frac{\Delta R_2}{R_2}}{1+\frac{\Delta R_1}{R_1}}-1\right]. \tag{12}$$

It is known from [6] that the change in resistance with the mechanical stressing of the wire can be determined from the relationship

$$\frac{\Delta R}{R}=\frac{S}{E}\cdot\frac{\Delta P}{q},$$

where S is the coefficient of sensitivity, constant for a given material within the limits of Hooke's law, E is the modulus of elasticity, ΔP is the variation in the tensile force and q the cross-sectional area of the wire.

Inserting this relationship into (11) we obtain the relation between the changes in the thermostat temperature Δt°_H and the variations in the stress of each arm of the bridge. If the winding of all bridge resistors is made with the same stress an expression similar to (12) will hold.

Variations of the thermostat temperature Δt°_{sh} due to the insulation resistance's not being infinite can be determined from (11) considering that $\frac{\Delta R}{R} = \frac{R}{R_{sh}}$, providing $\Delta R \ll R$, where R_{sh} is the insulation resistance.

The variation of the thermostat temperature due to the instability of bridge resistors depends on the aggregate action of all the factors. It follows from expressions (11) and (12) that stability requirements of the resistors become easier with an increase in the temperature coefficient of the resistance material from which the resistors R_1 and R_3 are made.

3. Instability in the operation of the amplifier due to changes in the supply voltage, circuit parameters and the gain of the amplifier.

Let the variation of an n-th parameter of the amplifier circuit or the supply voltage cause, with the amplifier input disconnected from the bridge diagonal (with an open system of control), changes in the bridge supply current equal to ΔI_M. The connection of the control system (of the amplifier) changes the bridge supply current making it equal to

$$\Delta I_{Mn} = \sqrt{\frac{\overline{A}}{R}}\left(\sqrt{T^{\circ} \pm \Delta t^{\circ}_{n}} - \sqrt{T^{\circ}}\right),$$

which causes a change in the thermostat temperature of Δt°_{n} and a change in the diagonal current equal to

$$\Delta I_{\partial n} = \frac{\alpha \Delta t^{\circ}_{n}}{4(m+1)}(I_M \pm \Delta I_{Mn}).$$

With an automatic balancing of the bridge the following relation holds

$$\Delta I_{\partial n} K = \Delta I_M - \Delta I_{Mn}. \qquad (13)$$

The degree of compensation of the change in the original current is expressed by the ratio $\Delta I_M / \Delta I_{Mn}$. In order to find this ratio let us divide expression (13) by ΔI_{Mn} and substitute ΔI_{Mn} and $\Delta I_{\partial n}$ by their values.

After transformation and taking into account (9) we obtain

$$\frac{\Delta I_M}{\Delta I_{Mn}} = |1+1| > 100, \qquad (14)$$

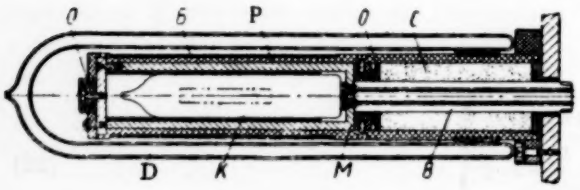


Fig. 4.

It follows from the above that, for practical temperature control circuits, variations of the n-th parameter of the circuit or the supply voltage (within the limits of the linear part of the dc-amplifier characteristic) have practically no effect on the bridge current.

Variations of the temperature inside the thermostat Δt°_{n} due to changes in the n-th parameter of the supply voltage can be determined from the expression for $\Delta I_{\partial n}$ taking into account (13) and (14).

$$\Delta t^{\circ}_{n} = \frac{4(m+1)\Delta I_M}{\alpha K I_M}. \qquad (15)$$

It follows from the above that temperature changes inside the thermostat depend, in the first instance, on the relative variations of the amplifier output current in an open system.

Variations in the amplifier gain, in themselves have no effect on the temperature inside the thermostat when the bridge is balanced. A drop in gain, however, lowers the capacity of the device to control the temperature within

given limits when factors affecting the temperature inside the thermostat are changed.

4. Variations of the temperature of the crystal due to changes in its operating conditions in the oscillator.

Temperature control inside the thermostat within the limits of the set error do not in themselves ensure the required temperature stability of the crystal element since the crystal itself dissipates energy in its oscillations. In order to decrease the additional heating of the crystal it is placed in hydrogen media under a pressure of several millimeters Hg.

Variation of the power dissipated by the crystal due to changes in the conditions of its operation in the oscillator circuit changes the temperature of the crystal element by

$$\Delta t^{\circ}_{\text{CT}} = \frac{\Delta U(\Delta U + 2U_m)}{2R_{\text{K}}A}, \tag{16}$$

where ΔU is the change of the voltage across the crystal with respect to voltage U_m, R_{K} is the equivalent active resistance of the crystal, and A is the thermostat constant.

It follows from this relation that in order to obtain a stable thermal operating condition for the crystal it is necessary to provide for it a stable electrical operating condition. This requirement is considerably stricter for thermostats with a small constant A.

A brief examination of the basic temperature errors in the thermostat when controlled according to the circuit in Fig. 2 leads to the following conclusions.

1. For reliable operation of the thermostat it is necessary to eliminate errors due to the ageing of materials, changes in the mechanical stress of wires in the resistor windings and changes in the insulation resistance (11) and (12). The existence of these errors cannot be discovered in the operation of the thermostat without additional measuring devices.

2. Errors due to changes in the ambient temperature (10) the operation of the amplifier (15) and the temperature of the crystal (16) can be discovered by a systematic measurement of the bridge current and eliminated by controlling the amplifier parameters.

Construction of the thermostat. The thermostat was assembled according to the circuit described above with the bridge components placed irregularly on the thermostat surface in order to compensate for the temperature gradient inside the temperature controlled chamber; this arrangement led to the final construction in the form of a closed metal cylinder covered by a layer of lagging material.

The thermostat cross section is given in Fig. 4, which shows that it consists of a closed copper cylinder M, serving to improve the temperature distribution inside the thermostat,and at the same time is an electrical screen for the contained crystal. The copper cylinder is fixed in the left-hand side of the plexiglas cylinder P with thick side walls which have narrow slits cut in them for fixing the bridge components O. The thicker right-hand side part of the plexiglas cylinder serves as a base for fixing the thermostat to the angle panel of the crystal oscillator. The outer surface of the cylinder has grooves cut in it for leads to the bridge resistors and for grounding the copper cylinder. Inside the thicker part of the plexiglas cylinder,between its middle partition and base, there is a screened lead-in B, made of a plexiglas rod with two longitudinal holes in it for the crystal lead-in wires,and with a metallized outer surface grounded at the point where the thermostat is fixed.

In order to improve lagging along the plexiglas cylinder and the screened lead-in,the space between them is filled with plexiglas shavings. The left hand side end wall of the plexiglas and copper cylinder are made detachable for mounting the crystal components.

Dewar's container D is used for lagging the thermostat, which makes the electrical power required to raise the thermostat to a given temperature very small.

Bridge resistors R_2 and R_4 are wound with manganin wire PÉShO of 0.2 mm diameter and resistors R_1 and R_3 with copper wire of 0.1 mm diameter which according to [7] is a good combination of materials for temperature changes in the range of 0-100°C. To ensure contact stability all the connections in the bridge are welded. In order to improve the stability of bridge resistors they were made of materials subjected to prolonged thermal

ageing at about 100°C which should provide a constant bridge balance temperature within the limits of 0.0003°C.

It follows from (11) that in the case of an equal-arm bridge, with equal insulation resistances R_{sh} shunting each arm, the latter resistances do not affect the bridge balance. In practice such a case is unlikely to occur and it is, therefore, advisable to find a minimum permissible value for resistance R_{sh}, whose variations in one arm of the bridge by a factor C would not produce temperature changes in the thermostat exceeding Δt°_{sh}. Let us solve equation (11) with respect to R/R_{sh} with the condition that $R_1 = R_2 = R_3 = R_4 = R$, $R_{sh\,1} = R_{sh}/C$, and $R_{sh\,2} = R_{sh\,3} = R_{sh\,4} = R_{sh}$.

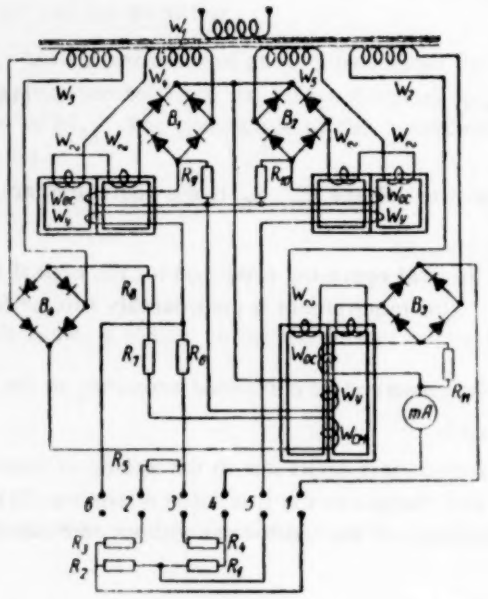


Fig. 5.

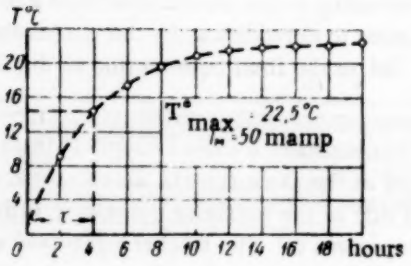


Fig. 6.

Considering that $\Delta t^{\circ 2}_{sh}\alpha^2 \ll 2\Delta t^{\circ}_{sh}\alpha \ll 1$ we obtain

$$\frac{R}{R_{sh}} = -\frac{2\Delta t^{\circ}_{sh}\,\alpha}{C-1}.$$

The minus sign shows that with a decreasing insulation resistance connected in parallel with resistance R the balancing temperature of the bridge increases by Δt°_{sh}. At C = 2, $\alpha = 0.004$, $\Delta t^{\circ}_{sh} = 0.0001$°C and R = 100 ohms, R_{sh} = 125 meg. The value of C = 2 was chosen on the basis of four year's experience with 10 thermostats when the insulation resistance never fell to less than 1/2 of its initial value. The actual insulation resistance with plexiglas insulators is greater than the required value and amounts to some 500 meg.

As has already been pointed out, a more even temperature distribution in the thermostat was obtained by an irregular distribution of the bridge components over the surface of the plexiglas cylinder, corresponding to the heat dissipation of these surfaces. Measurements of temperature differences at the base of the plexiglas cylinder and in its central part (by means of thermocouples with an error of some ±0.0003°C) showed that with a thermostat temperature of some 40°C an even temperature distribution is attained within the accuracy of measurement, if one of the manganin resistors is placed in the right base of the plexiglas cylinder and half the other manganin resistor inthe left base, and the other half of this resistor and the two copper resistors on the side surface of the cylinder, at a distance proportional to the dissipated power.

Variations of the thermostat temperature of ±5°C produced temperature differences at the base of the cylinder with respect to its middle up to ±0.003-0.005°C.

With a copper cylinder incorporated, changes of the thermostat temperature of ±5°C produced variations of temperature at the base of the copper cylinder, with respect to the mean, of up to ±0.001°C.

The resistance of the bridge arms was chosen so that balance was obtained at some 38°C. A fine adjustment of the thermostat was attained by an additional manganin resistor connected in one of the bridge arms as shown in Fig. 5. The winding of the bridge resistors was made at a constant tension of some 5 g at a temperature of the surrounding air of 21°C.

Thus, it can be assumed that the ageing of bridge resistors, variations in the shunting resistances and changes in tension of the wire will not cause errors exceeding 0.005°C.

The thermal design of thermostats has been dealt with in several papers [8] and will not be repeated here. In designing thermostats, however, the parameters of the materials used are not always known with sufficient accuracy and it is advisable to verify experimentally the time constant and the temperature constant of the type of thermostat selected for use.

The time constant of the thermostat can be obtained from the curve of the thermostat temperature against time at a given current feeding the thermostat as shown in Fig. 6. The time constant is determined as the time it takes the thermostat to reach a temperature 0.63 of the stable value. The relationship of the difference temperature T° and the power dissipated in the thermostat is determined by setting the bridge current at several values and determining the stable temperature difference T° for each value. For the construction in question this relationship is shown in Fig. 7. It follows from above curves that the thermostat constant is equal to $A = 0.011$ w/°C and the time constant to $\tau = 4$ hours.

The relations shown in Figs. 6 and 7 were obtained by placing the measured thermostat inside another thermostat kept at 22°C. When these curves were plotted the error (up to 3%) due to the variations of the power dissipated in the bridge with an additional resistor were not taken into account.

Amplifier. The amplifier parameters are determined on the basis of given values: the ambient temperature t°_1, its variations ΔT°, the maximum T°_{max} and the minimum T°_{min} differences of temperature inside and outside the thermostat within whose limits the temperature must be controlled with an error of Δt°, and the bridge resistance R. The experimentally determined thermostat constant A is also taken into account.

For the instrument in question these quantities have the following values: $t^\circ_1 = 22$°C, $\Delta T^\circ = 0.5$°C, $T^\circ_{max} = 20$°C, $T^\circ_{min} = 10$°C, $\Delta t^\circ = 0.002$°C, $R = 100$ ohms and $A = 0.011$ w/°C.

A two stage magnetic amplifier shown in Fig. 5 with an $m = 1$ was used. It was fed from a ferroresonance stabilizer.

From (8) we find the maximum $I_{M\,max} = 0.047\,\alpha$ and the minimum $I_{M\,min} = 0.033\,\alpha$, values of current limiting the operational characteristic of the amplifier, and its gain $K = 26{,}000$ for the minimum temperature value in the given range.

The first stage of the amplifier is connected "push-pull," but the second is single-ended with a positive feedback controlled by resistors R_1, R_2 and R_3. The first amplifier stage uses permalloy laminations 80NKhS 0.45 mm thick in two cores each of 10 rings of 46/32 mm diameters. The ac windings $w_\sim$ have 700 turns, the feedback windings w_{oc}, 730 turns and the control windings w_y, 4500 turns each. In the bridge circuits B_1 and B_2 detectors type DGTs-1 are used. The voltage across windings w_4 and w_5 is about 1.5 v.

The second amplifier stage uses permalloy N-79M laminations 0.2 mm thick in two cores each of 25 rings 57/ 33 mm diameters, $w_\sim = 1300$ turns, $w_{oc} = 1350$ turns, $w_{cM} = 200$ turns and $w_y = 1400$ turns. The bridge B_3 consists of DGTs-8 rectifiers and B_4 of DGTs-1 rectifiers. The voltage across winding w_6 is about 30 v. All the windings of the first and second stages are wound with PEShO wire of 0.2 mm diameter. The layers are insulated by varnished cambric or plexiglas tape. The insulation resistance between the input and output of the amplifier is about 500 meg. The bias of the second stage is controlled by resistor R_6 consisting of a constant resistor selected for each amplifier and two resistance decades of 10 ohms × 10 and 100 ohms × 10 for controlling the amplifier during operation.

The bridge balance temperature is controlled by resistor R_8 and the method of connecting it. When terminals 2-2 and 3-3 are shorted the temperature is set at 38°C and lower; when 2-3 and 3-2 are shorted it is set at 38°C and higher. Resistor R_4 is a shunt for an external galvanometer for measuring ΔI_∂.

Due to the variation of the detector parameters with temperature, an instability in the operation of the amplifier with variations in the ambient temperature was observed as shown in Fig. 8, where curve A is the amplifier characteristic at 19°C and curve B at 29°C. The temperature effect of the first stage is greater than that of the second stage due to changes in its positive feedback. The making of resistors R_2 and R_3 from copper wire provides an amplifier characteristic with the same slope as before.

In the case when connecting a copper-wire resistor produced over-compensation in temperature measurements, a manganin resistor is connected in series with copper resistor and the required compensation attained by

selecting appropriate values for them. The reduction of current in each half of the first stage by reducing the ac voltage, with the object of reducing the temperature instability of the stage, raised the stability of operation of the amplifier as a whole, although it reduced its gain.

The temperature instability of the second stage can be attributed to the decrease in the resistance of rectifiers in the biasing circuit, and compensated by making the greater part of the resistor R_6 from copper wire.

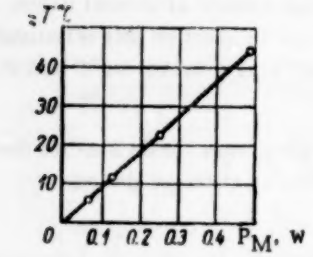


Fig. 7.

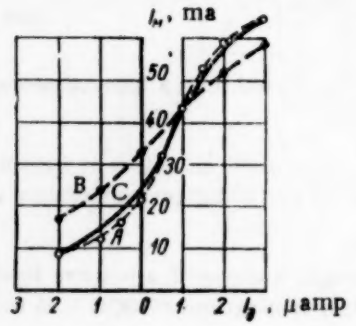


Fig. 8.

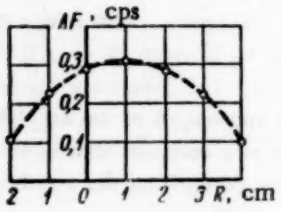


Fig. 9.

Above method of controlling one stage at a time provides an almost complete elimination of the effect of ambient temperature on the operation of the amplifier, which is shown by curve C (Fig. 8) taken at 29°C.

Adjustment of the set. After the characteristic of the amplifier is obtained and the bridge connected in accordance with Fig. 5 the amplifier input should be shorted and the bridge current adjusted by means of resistor R_6 (with R_7 set to the middle position) to a mean value of its characteristic or to a value calculated from (8) if the operation temperature of the crystal is given.

R_5 is replaced by a resistance box. When the supply voltage is connected the bridge current should rise to the maximum value obtainable with the given amplifier, since the bridge current is large at unbalance. As the thermostat heats up the amplifier input current will decrease to the stable value. If the bridge current remains practically zero when the thermostat is connected (providing the amplifier circuit is not faulty), the amplifier input winding should be reversed.

The thermostat is adjusted to work at a definite temperature for a given crystal by connecting the required value of resistor R_5, which is determined by obtaining beforehand the relation between the bridge balance temperature and the value of resistor R_5.

If the operating temperature of the crystal is unknown, the optimum conditions of its operation are obtained by determining the relation between the crystal oscillator frequency and the thermostat temperature, by varying the values and method of connecting R_5 are shown for a bar-shaped crystal in Fig. 9. Each frequency measurement is made in this case only after a complete stabilization of temperature in the thermostat. In this instance zero-frequency variations with temperature correspond to $R_5 \simeq 0.9$ ohms. After finding the optimum temperature by varying resistor R_5, it is necessary to find the relationship between ΔI_∂ and R_7 and, by adjusting R_7, obtain $\Delta I_\partial = 0$. This concludes the adjustment of the thermostat to a definite temperature of operation.

The checking of the thermostat temperature is made by means of a galvanometer which measures the bridge unbalance current ΔI_∂ and a milliammeter at the output of the amplifier which measures current I_M. Galvanometer readings indicate the deviation of the thermostat temperature from the bridge-balance temperature due to the ambient temperature, amplifier parameters, and its operating conditions. The milliammeter readings indicate the thermostat temperature changes due to the ambient temperature variations and large changes in the bridge resistances. As has already been shown the variations in the parameters and operational conditions of the amplifier have practically no effect on I_M; hence, the milliammeter readings will not reflect these variations.

Under normal operating conditions a record of the value of ΔI_∂, I_M and $\Delta T°$ will provide an analysis of the causes of thermostat temperature changes in the following way. Components $\Delta I_{\partial x}$ and ΔI_{Mx}, due to the ambient temperature changes by $\Delta T°_1$, must be excluded from the galvanometer readings $\Delta I_{\partial 1}$ and the milliammeter reading variations ΔI_{M1}. It follows from (8) and (10) that $\Delta I_{\partial x} = \frac{\alpha \Delta T°_1}{8\Pi} \sqrt{\frac{A}{R}(\ell° \pm \Delta T°_1)}$; the difference

$\Delta I_{\partial 1} - \Delta I_{\partial x}$ is due to the variations of the parameters and the supply conditions of the amplifier, which are compensated by changes in the biasing of the second stage of the amplifier by means of resistor R_7. The difference $\Delta I_{H1} - \Delta I_{Hx}$ represents the variations of temperature which keep the bridge balanced $T^\circ - T^\circ_1 = R/A\,(I^2_M - I^2_{M1})$. In practice the accuracy of reading of a pointer instrument is no better than 0.5 ma which corresponds to temperature change up to 0.3°C.

SUMMARY

The thermostat here described ensures a constant operating-temperature for the crystal with an error not exceeding ±0.002°C with a temperature change of the medium surrounding the thermostat not exceeding ±0.5°C. An appropriate supervision of the work of the whole equipment provides even a smaller thermostat temperature variation, which is caused in the main by changes of the bridge parameters with time.

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SETS OF REFERENCE STANDARDS FOR CHECKING Q-METERS

A. L. Grokhol'skii

With the object of improving the accuracy of measurements the Novosibirsk State Institute of Measures and Measuring Instruments (NSIMMI-NGIMIP) worked out a method of checking Q-meters KV-1 and UK-1, which are the most commonly used in the USSR. This method was incorporated in Instruction 203-56 of the Committee of Standards Measures and Measuring Instruments.

The checking of Q-meters is based on reference standards developed and made by the NSIMMI. The first consignment of these standards has been dispatched by State Inspection Laboratories for Measuring Equipment.

The set consists of eight coils with a known Q-factor, four high-frequency capacitors and auxiliary equipment.

Seven of the coils have a set Q-factor calibrated in the range of 50 kc to 100 Mc. The coils have multilayer, single-layer and frameless windings depending on the frequency they are designed for. All the coils are mounted on ceramic bases. In order to obtain greater stability of the basic electrical parameters the coils are hermetically sealed.

The eight coil serves to check the Q-meter scales. It has five set Q values from 50 to 250 calibrated at 10 Mc.

The set of coil provides an over-all check of Q-meter errors.

In the certificate issued with each coil a Q value is given which would be indicated by a KV-1 or UK-1 instrument in perfect working order and not the actual Q value of the coil. This is due to the fact that although instruments KV-1 and UK-1 are called Q-meters they do not actually measure the quality of the coil. They measure voltage amplification, i.e., the ratio of the voltage across the tuned-circuit capacitor at resonance of the tuned circuit to the emf supplied to the circuit.

The certificates issued with the coils take into account the effect of their self-capacity, the shunting effect of the tube voltmeter and the effect of the coupling-series resistance of 0.04 ohms in the KV-1 instrument.

All the Q values of coils are certified with an error not exceeding 3% up to 25 Mc and 5% up to 100 Mc.

If the actual Q values of a tested coil is required it is necessary to apply corrections to the readings of a checked instrument for the errors enumerated above. If corrections are not applied it is quite possible under certain conditions to measure the same coil at the same frequency on two Q-meters KV-1 and UK-1 both in perfect working order and obtain a discrepancy of 10 to 15%.

Often Q-meters are used for measuring impedances at high frequencies. These measurements are usually made by the substitution method, i.e., the measured impedance is determined by the capacity of the condenser which substitutes it. The residual inductance of this condenser can distort the measurement considerably. This inductance is checked by determining the frequency error when measuring capacity at a high frequency by means of high-frequency coaxial capacitors with a nominal value of 20, 50, 100 and 200 $\mu\mu$f.

Since the condenser of instrument KV-1 is checked in this way at 25 Mc and that of UK-1 at 100 Mc the coaxial capacitors are calibrated at these frequencies. The error of their calibration does not exceed 0.5 to 1%.

These known Q-coils can be used for checking high-frequency inductance bridges IIEV-1 for which purpose the coil certificates gives their effective inductances.

The coaxial capacitors can also be widely used as high-frequency standards of effective capacity whose values are determined by low-frequency measurements on low frequency bridges and corrected for high frequencies by calculation based on their geometrical dimensions and the test frequency. In this instance their error need not exceed 0.1 to 0.2%. The set can also be used for checking Q-meters type 160a, 170a, and 622c.

AN APPLICATION OF THE VVT-D (3003) WAVEMETER

V. Ia. Volodarskii

By a simple alteration of the crystal oscillator the high-precision decimeter wavemeter VVT-D (3003) can be made to provide frequencies of 1 Mc, 100 and 10 kc with an error of $\pm 5 \cdot 10^{-6}$.

For this purpose the set should be opened and terminal No. 25 of terminal strip No. 202 (mounting plate PSP-10) connected to a coaxial cable whose other end should be soldered to a high-frequency socket mounted on the front panel or any other convenient place of the cabinet. (The designation of terminals and terminal strips in both version VVT-D and 3003 of the wavemeter are the same).

The value of the frequency will be determined by the position of the "Calibrate" switch. When it is in the "1 Mc" position there will appear a voltage of 1 Mc at the output. In the "100 kc" and "10 kc" positions corresponding frequencies will appear at the output but the shape of the voltages will be distorted on account of the presence of higher harmonics. Thus,a 100 kc voltage will have a 1 Mc voltage and a 10 kc will have 100 kc and 1 Mc voltages superimposed on it. Sometimes this circumstance can be utilized for obtaining a "network" of reference frequencies.

If, however, a voltage approaching a sinusoidal shape is required, it can be supplied to the output through a filter.

In order to obtain frequencies lower than 10 kc, a frequency divider can be used which would provide a range of reference frequencies from 100 kc to 1 Mc with an accuracy of $\pm 5 \cdot 10^{-8}$.

MEASUREMENTS OF VOLUME

ERRORS IN THE CALIBRATION OF HORIZONTAL VESSELS

V. I. Loshak

In the generally used geometrical method for the calibration of vessels, the accuracy in the construction of the calibration tables is determined by the two main factors: the precision of the methods used to measure the linear dimensions from which the capacity of the vessel is calculated, and the degree of approximation of the shape of the vessel to that of a true cylinder.

A general estimate of the accuracy in calibration attained may be derived, starting from the following considerations.

The contents of a horizontal vessel, filled to a height $\underline{h}$ is given by the formula:

$$U_h = U_c K_c + 2U_e K_e, \tag{1}$$

where U_h is the capacity of the filled part of the vessel, U_c is the total capacity of the cylindrical part of the vessel, K_c is the filling coefficient of the cylindrical part of the vessel, U_e is the total capacity of one end, K_e is the filling coefficient of the end.

In the case of vessels with spherical or conical ends, the capacity of the cylindrical part is usually very much greater than that of the ends. Thus, the error in the construction of the calibration table is mainly determined by the error in the calibration of the cylindrical part of the horizontal vessel.

Let us consider the calibration error for the cylindrical part of a horizontal vessel, which corresponds to the calibration error for a vessel with flat ends.

In this case, the contents of a horizontal vessel, filled to height $\underline{h}$, will be

$$U_h = \frac{\pi}{4} D^2 L K_c, \tag{2}$$

where D is the rated diameter of the vessel, L is the length of the cylindrical part, K_c is the filling coefficient of the cylindrical part of the vessel, calculated from the formula

$$K_c = \frac{1}{\pi}\left[\arccos(1-2H/D) - 2(1-2H/D)\sqrt{H/D-(H/D)^2}\right]. \tag{3}$$

Substituting this value of K_c in (2), we obtain

$$U_h = \frac{D^2 L}{4}\left[\arccos(1-2H/D) - 2(1-2H/D)\sqrt{H/D-(H/D)^2}\right]. \tag{4}$$

On the basis of the latter equation, the relative error, δ_{rv}, in the determination of the capacity of the filled part of a vessel with flat ends, is given by the rule of the sum of the squares of the partial errors in the rated values of diameter, length and filling height, according to the equation

$$\delta_{rv}=\frac{dU_h}{U_h}=\sqrt{\left(\frac{\partial U_h}{\partial D}\right)^2\delta_{rD}^2+\left(\frac{\partial U_h}{\partial h}\right)^2\delta_{rh}^2+\left(\frac{\partial U_h}{\partial L}\right)^2\delta_{rL}^2}, \quad (5)$$

where δ_{rD} is the relative error in the rated diameter of the vessel, δ_{rh} is the relative error in the rated height of filling, δ_{rL} is the relative error in the length of the vessel.

Solving (5), we finally obtain

$$\delta_{rv}=\sqrt{(2-N)^2\delta_{rD}^2+(N\delta_{oh})^2+\delta_{rL}^2}. \quad (6)$$

where N is a coefficient, dependent on the relative height of filling, calculable from the formula

$$N=\frac{H}{D}\,\frac{8\sqrt{H/D-(HD)^2}}{\arccos(1-2H/D)-2(1-2H/D)\cdot\sqrt{H/D-(H/D)^2}} \quad (7)$$

Values of N are given below for different heights of filling.

H/D	0.10	0.25	0.50	0.75	0.90	1.00
N	1.48	1.42	1.27	1.03	0.72	0

It follows from (6) and the table of values of N that the error in the determination of the content, associated with the error in the determination of the rated diameter multiplied by (2 −N), alters from $2\delta_{rD}$ for complete filling, to $\sim\delta_{rD}$ for filling up to height 0.75 D, and to $\sim 0.25\,\delta_{rD}$ for filling up to height 0.1 D. The explanation of this change in the value of the error, depending on the degree of filling, is that the error in the determination of the rated diameter and the consequent error in the determination of the filling coefficient, K_c, have opposite signs, so that the total error in the measurement of content passes through a range of values.

Let us estimate the errors involved in (6).

There are two sources of error involved in the relative error of the determination of the diameter of the vessel: error in the actual measurement of diameter, and error arising from differences in diameter of various sections along the length of the vessel.

The first of these involves the accuracy of measurement of the diameter, and, with existing means of measurement, it may be estimated that the maximum partial error is given by $\Delta D = \pm 3$ mm.

Depending on the magnitude of the diameter, the relative error, δ_{rD}, for standard vessels, will be

$$\delta_{rD}=\frac{\Delta D}{D}=0.1\div 0.2\%.$$

The second factor depends on the nature and degree of divergence of the shape of the vessel from that of a true cylinder, lying horizontally, and on the taking into account of these divergences by the method of measurement. Let us consider the most characteristic case of a vessel of diameter 2000 mm, with a variation in diameter of 10 mm along its length.

Suppose the vessel has the shape of a truncated cone. If one of the limiting diameters is used, then the error in the determination of the rated diameter will be $\delta_{rD} = \pm 0.5\%$.

Suppose the vessel is barrel shaped. If the maximum diameter is used, then the error in the determination of the rated diameter will be $\delta'_{rD} = +0.3\%$.

If the minimum diameter is used, then the error will be $\delta''_{rD} = -0.7\%$.

Divergences from a true cylinder, in the form of an oval or elliptical cross section, will also produce errors in measurement.

This error arises from the fact that, when measuring, the length of an ellipse is used for the length of a circle. We obtain by measurement: $L_{circ} = L_{ellip}$ or $2\pi R = 2\pi af(b/a)$, whence $R = af(b/a)$.

For values of b/a from 1.0 to 0.95,

$$R \simeq a\sqrt{\frac{b}{a}} \simeq \frac{a+b}{2}.$$

The relative error due to ellipticity will be equal to the error in the determination of the cross-sectional area, arising from the replacement of the area of an ellipse by the area of a circle, with a perimeter equal to that of the ellipse. This error is given by the following relation:

$$\delta_e = \frac{\pi R^2 - \pi ab}{\pi ab} = \frac{1 - b/a}{4\ b/a},$$

for b/a = 0.99; 0.98; 0.95; δ_e (%) = 0.0025; 0.012; 0.065.

In practice, an ellipticity of greater than b/a = 0.98 is only conceivable with a distorted vessel, since a value of b/a = 0.98 is already equivalent to a tilt of the vessel axis at an angle of 12°.

A relative error in the rated height of filling can arise from the fact that, when constructing the calibration table, the height of filling is reckoned from a nominal zero.

Since the "measuring" diameter, in the proximity of the orifice, may differ from the rated diameter, the actual height of filling may differ from the rated height by an amount Δh. The relative error in the rated height of filling, arising from this, may be calculated in the following way:

$$\delta_{rh} = \frac{\Delta h}{H} = \frac{1}{D} \cdot \frac{\Delta h}{H/D} 100\%.$$

Let us consider a typical case. For a tank in the form of a truncated cone, the rated diameter will be equal to the semisum of the end diameters. With an orifice at one end of the vessel, the "measuring" diameter will differ from the rated diameter by the amount

$$\Delta = \frac{D_b - D_m}{2}.$$

For a reservoir filled to height h, the rated degree of filling will be h/D, but the actual degree of filling (along the measuring diameter) will be $h/(D + \Delta)$.

The relative error in the rated height of filling will be

$$\delta_{rh} = \frac{H/D - H/(D + \Delta F)}{H/D} = \frac{\Delta}{D + \Delta}$$

so that, with D = 2000 mm and Δ = 5 mm, δ_{rh} = 0.25%.

Let us consider the value of the error in the determination of the rated height of filling for an elliptical vessel. The rated diameter of an elliptical vessel is equal to the sum of the semiaxes: D = a + b. The error in

the determination of the rated height of filling will be

$$\Delta h=(D-2b)\ H/D=(a-b)\ H/D,$$

so that the relative error is given by

$$\delta_{rh}=\frac{\Delta h}{H/D}\cdot\frac{1}{D}=\frac{a-b}{a+b}=\frac{a/b-1}{a/b+1}.$$

The errors δ_{rh} is simply related to the error, arising from it, in the determination of the filling coefficient, which is taken into account in (6) by introduction of the coefficient N. The table below shows values of $N\delta_{rh}$ as percentages, for a vessel of diameter 2000 mm, for different ratios of the semiaxes of the ellipse, as functions of the height of filling.

a/b \ H/D	0,1	0,25	0,5	0,75	0,9
1.002	0.15	0.14	0.13	0.1	0.07
1.005	0.37	0.36	0.32	0.26	0.18
1.01	0.74	0.71	0.64	0.52	0.36
1.02	1.46	1.41	1.26	1.02	0.72
1.05	3.6	3.46	3.1	2.52	1.81

A similar source of error occurs if the axis of the vessel is not horizontal. The value of this error, even with a TU admissible slope of 1 in 100, already amounts to 0.2 to 10%, depending on the height of filling (the greatest value corresponds to the least height of filling).

The relative error in the determination of the length of the vessel

$$\delta_{rL}=\frac{\Delta l}{L}.$$

If it is assumed that the length is measured to an accuracy of ±2 mm, then, for standard vessels, depending on their length,

$$\delta_{rL}=0.05\text{ to }0.1\%.$$

It is evident from the above analysis of sources of error that a most important role, in the precision of calibration of horizontal cylinders, is played by the divergence of the shape of the vessel from that of a true cylinder.

In order to reduce the calibration error, it is therefore necessary to determine the rated diameter of the vessel by measurement of the diameters in various directions; from these measured diameters it is possible to derive the degree of distortion of a cross section of the vessel.

This procedure enables us to reduce the calibration error, arising from error in determination of the rated diameter, to a value not exceeding ±0.5%, and the error due to the oval nature of the section to 0.2-0.4%.

On the basis of the above results for the partial errors of measurement, the maximum total relative calibration error, calculated from (6), amounts to 0.5-0.7% for typical vessels, from half full to completely full.

For lower heights of filling, the relative calibration error increases to 1% and above, but, because of the small content, the absolute value of the error will be less at these heights of filling than when the vessel is half full, or nearly full.

For horizontal vessels of small capacity (up to 10-15 m^3), the maximum relative calibration error may be taken as 1%.

For vessels in which the departure from the shape of a true cylinder exceeds the TU permitted value, the relative calibration error may be up to 1.5-2%, even when the measurements are well done, and may amount to 3-5%, if calculation of the distortion is not carried out carefully.

REVIEWS AND ESSAYS

TECHNICAL INSPECTION AND EMPLOYMENT OF INSTRUMENTS AT BRITISH CHEMICAL PLANTS

S. S. Shchedrovitskii

According to an estimate of British specialists the cost of instrumentation at contemporary chemical enterprises amounts to from 5 to 15% of the total capital investment. The lower figure pertains not to little-automated and poorly instrumented enterprises but to such specialties and plants where operating conditions (for instance, high pressure) require more costly technical production equipment, whereby the relative figure for expenses on instrumentation is lowered.

As an example we shall give some data on the Billingham Chemical plant of the Imperial Chemical Industries trust. This plant covering an area of 300 hectares put out yearly over 1,800,000 metric tons of various chemical products, and has 13,500 employees.

The total number of instruments for measurement of output exceeds 6000. Over 95% of output measurements is carried out by means of diaphragm or membrane-type differential manometers. By way the greatest majority of measurements have as their objects the control of production processes; in this case constancy of indications and dependability of the instruments is more important than their accuracy. About 3% of the total number of production measuring devices serve for cost determination or efficiency estimation; for these purposes, accuracies of 1 to 2% are required, which are obtained by careful, regular servicing and maintenance. Automatic recorders are used only in measurements connected with mutual accounts and for obtaining data on process characteristics.

Temperature measurements cover a range from −200 to 1200°C. The most frequently used temperature sensing elements are iron-constantan thermocouples, which provide in the range between +100° and 600°C an accuracy better than 1.5%.

Measurements in the low temperatures range are carried out by means of platinum resistance thermometers. Manometer type thermometers are used only in specific places, where installation of electrical thermometers is not justified. When there is a large number of points to be controlled, a commutator is used, which periodically connects the transducer to the measuring devices at the various control points, whereby in succession indications of the values of the measured quantity at these points are obtained, and in case the measured quantity exceeds permissible limits an alarm is given. For example, each of 144 thermocouples, which are used to control the temperatures of various bearings and valves is connected once in every 3 to 5 minutes to a common single recorder. In all there are at this plant over 1000 indicating and recording instruments for measurement of temperature.

Measurements of pressure are carried out at this plant at more than 10,000 points within a range beginning with high vacuum up to 350 kg w/cm^2. The most widely used instrument is a pointer pressure gauge employing a Bourdon spring and having a scale diameter of 150 mm. Frequent cases of destruction of these instruments from fatigue were observed, when pulsating pressures were measured; good results were obtained, when they were replaced by instruments using tubular springs made of alloy steel with the addition of capillary damping devices. In most cases of pressure measurements, an error of ±1% is entirely satisfactory. When higher precision is required, weighed piston type manometers are used.

There are at this plant more than 1200 regulators; there are also a considerable number of level indicators, various analyzers and other instruments and apparatus for measurement and control.

The instrument department of the plant has 300 employees and consists of three sections: the development and engineering section, the operations section and the research section. The operations section is in charge of the central repair shops and also provides procedural direction for the departmental instrument sections, which are under the supervision of the various department heads.

The number of instruments serviced by one man varies, depending on their complexity between 75 and 200. On an average, the number of instruments taken care of by one technician is 100; to every five technicians there is one "brigadier." These data are in good agreement with statistical data on time consumed for technical supervision of various types of instruments according to observations of the firm of Distiller Co (Tables 1 and 2).

TABLE 1

Subject of measurement	Type of instrument	Man-hours per year
Output quantity	Differential-manometer-type quantity meters with diaphragm membrane or bellow elements	10
	Quantity meters with float-type dif. manometers	15
	The same with bell-type dif. manometers	15
	The same with ring-balance dif. manom.	15
	Glass-tube rotameter	10
	Water meter with rotating vane	5
Pressure	Pointer-type vacuummeter	5
	Pointer-type manometer	5
	Pointer-type tensionmeter	5
	Differential pressure transducer with pneumatic output signal	25
	Same with electrical output signal	25
Level	Bubble levels	2
	Float-type level indicator	5
	Pneumatic level indicator	15
Composition of material	Automatic CO_2 gas recorder	100
	Automatic density recorder for liquids	45
	Same for gases	50
	Recording calorimeter	60
	Recording calorimeter	50
	Recording conductivity meter	90
	Recording pH meter with glass electrodes	75
	Same with calomel electrodes	50
Various	Automatic conveyer balance	100
	Automatic platform balance	100
	Mechanical tachometer	20
	Electrical tachometer	10
	Flame indicator	20
	Clock	50
	Timer electrical	10
	Timer, multipoint electropneumatic	35

The use of automatic recording or controlling devices in place of the indicating instruments listed in Table 1 involved additional expenditures of time for technical supervision and servicing. Orientation data on such additional time expenditures are presented in Table 2. The data in this table do not include the time spent in changing the charts and refilling of pens with ink on automatic recorders. Experience has shown that for this purpose 30 man-hours per year for each automatic recorder are required.

The departmental instrument sections are responsible for dependable operation of all instruments in their particular department and for the accuracy of the measurements made by their use. Each department has its own instrument shop in which small repairs are carried out, as well as calibration and adjustment of instruments; there is also a storeroom for everyday needs.

At the place where an instrument is installed only trial runs and zero corrections are carried out; for repairs the instrument is taken to the instrument repair shop.

Such an organization of supervision and repair requires that the instrument department must foresee the problems of unification and interchangeability of various instruments already in the project stage; and during replenishing of equipment the needed quantity of instruments, and of spare and replacement parts must be ordered to carry out a planned program of maintenance and repair. At the same time the needs for replenishing of the shops with equipment and materials for checking and calibration of instruments must be taken care of. However, no equipment or supplies for making of spare or replacement parts should be contemplated, because one of the basic rules of organization of the instrument operation department is that spare and replacement parts should be supplied only by the instrument manufacturer.

TABLE 2

Type of instrument	Man-hours per year
Recorder or recording mechanism w. daily chart	3
Pneumatic converter	10
Secondary pneumatic indicating instrument	3
Secondary pneumatic recording instrument	6
Pneumatic regulator	10
Pneumatic remote-control device manually operated	10
Automatic pneumatic valve	5
Pneumatic positioning device for valve	20
Indicating galvanometer	15
Recording galvanometer	25
Potentiometer, mechanical, indicating	20
Potentiometer, mechanical recording	40
Potentiometer, electronic, indicating	15
Potentiometer, electronic indicating	25
Failure-announcing system	20

The firm Distiller Co. recommends that two cards be provided for each instrument: an inventory card and a current-state card. The inventory card contains all characteristic data on the instrument; the current state card is used to enter all data on calibration and repair operations.

The departmental instrument sections are also charged with all the work of installation and mountage of instruments and of their modernization.

The plant instrument departments carry out, mainly, work on planning and designing of instrumentation for new departments and production lines. They also carry out development work on new, specific instruments, which are not manufactured by instrument manufacturers. Experimental models of such instruments are made up in the instrument shop of the plant, and then after they have been tested are transferred for commercial production to some instrument manufacturing company.

INFORMATION

CONFERENCE ON VIBRATIONAL OSCILLOGRAPHS

From March 4 to 6, 1958 there took place in Leningrad a scientific and technical conference on vibrational oscillographs. This conference was called by the State Planning Committee of the SSSR, the State Planning Committee of the RSFSR, by the administration of the Instrument manufacturing Industry of the Leningrad Soviet of National Economy and by the All-Union Scientific-Research Institute of Electrical Measuring Instruments. The objects of the conference were: the exchange of experience between the organizations which are carrying out development and production of vibrational oscillographs, electrocardiographs and of other instruments with photographic recording of indications; the review and generalization of requirements of the organizations employing oscillographs under various conditions for solution of various problems; and the working out of recommendations for further direction of the development of oscillograph construction, for specialization of production and for promotion of oscillograph nomenclature.

An instrument show was arranged to take place simultaneously with the conference, in which there were exhibited many types of oscillographs from our country as well as from the German Democratic Republic, from Sweden and other countries.

In the work of the conference participated more than 250 delegates, which represented about 100 organizations located in Moscow, Leningrad, Kharkov, Kishinev, Kuibyshev, Podol'sk, Viln'yus, Penza and other cities.

M. E. Rakovsky, in his introductory remarks, pointed out the constantly increasing importance of oscillographs for research as well as for production and technical purposes. The speaker emphasized, that the satisfaction of the requirements of the numerous users of various types of oscillographs can be accomplished only by means of a well considered choice and standardizat on of basic types, unification of components and their combinations and also by the use of modular construction.

The present status of oscillography in our country was reviewed in the paper of E. S. Borisevich. In the Soviet Union there have been developed and are now produced 20 different models of oscillographs. Systematic development and research in the field of oscillography is carried out by a number of industrial plants, research and development institutes and universities.

With respect to design and basic performance characteristics, many of our oscillographs are not surpassed by the best models of those manufactured in other countries; however, the quality of their production and finish do not always satisfy the users. The output of oscillographs (of universal as of special types) is far from satisfactory. Coordination of work is absent; communication between the various organizations that carry out design and production of oscillographs is only of an incidental nature; their requirements for special materials (light sources, semiconductor rectifiers, high-remanence magnets, thin copper and aluminum wire, etc.) are not fulfilled in sufficient quantity. The output of accessories, such as amplifiers, integrating and differentiating attachments etc. is not organized.

Evaluating the basic tendencies of recent developments in oscillography E. S. Borisevich pointed out the widespread use during recent years of multichannel oscillographs with moving-coil galvanometers.

The development of such galvanometers with natural frequencies up to 10,000 cps and the possibility of arrangement of several of them in a common magnetic system has made it possible to produce very portable multichannel universal oscillographs, which are used in various industrial and field applications. Our moving-coil galvanometers are not surpassed by galvanometers of the best manufacturers abroad.

The most important problem in oscillograph development Borisevich considers to be the creation of a universal stationary oscillograph with a high degree of automation of measurements; the development of an oscillograph which would have a direct-recording system that does not require development or any other "wet" processing; the development of accessories to oscillographs, among others, those with memory devices; standardization of metrological, that is of accuracy characteristics of galvanometers and oscillographs, and working out of corresponding norms and standards.

A number of papers (by G. P. Lebedev, V. A. Dmitriev, E. S. Borisevich, I. P. Molotkov and others) were devoted to descriptions of designs of oscillographs produced by our various organizations.

The greatest interest was evoked by a series of papers, which were devoted to new directions in the development of oscillograph design. B. A. Seliber reported on the development of a new series (N130) of moving-coil-type vibrators with magnetic induction damping.

Another direction in which work on the improvement of vibrators is going on was reviewed on the report by L. M. Guralnik: in the new vibrators of serial numbers 135 and 136 the suspension is surrounded by short pieces of tubing filled with a liquid providing a kind of lumped damping; by this method, the range of recorded frequencies is considerably widened, and the sensitivity of the vibrators is increased relatively to those now in production.

One of the most promising directions in the development of oscillograph construction is the change of a system of graphic recording, that does not require development, fixation and drying, which sharply decrease the time for obtaining a finished oscillogram. To this question were devoted reports by I. I. Zhilevich, Ya. Zeidenberg and A. A. Zaslavsky.

I. I. Zhilevich reported on electrographic methods of recording and on the development of a special paper for this purpose. This paper consists of a base layer coated with a thin film of an insulating resinous material in which particles of a light-sensitive semiconductor material are dispersed. Prior to use, the paper is given a uniform electric charge by means of a corona discharge, and in this condition it becomes sensitive to light. When now a light ray strikes the paper, the resistance of the semiconductor material is changed, and this produces a local change of potential. In this way an invisible record is created in the shape of a line on which the electric charge is radically different from the charge on the rest of the surface. To "develop" such a paper, dusting with a charged colored powder is used, which is attracted by the invisible recorded line. The speaker reviewed various possible schemes for electrographic recording systems and demonstrated in operation a device for rerecording, in enlarged size on electrographic paper, of an oscillogram from a moving picture film.

Paper with electrographic recording so far permits only relatively slow motion of the light way. In this respect more promising are the possibilities offered by the use of photographic paper with direct blackening. For recording on such a paper a powerful source of ultraviolet radiation is used (a high pressure mercury lamp). At a velocity of the light ray up to 2 m/sec a directly visible record is produced; at higher velocities of the recording ray a "development" is necessary, which is carried out by illumination of the paper with an ordinary electric light bulb for 10-20 sec. Successful development of this paper has made it possible to start design of a new type of oscillograph, which undoubtedly will find wide approval.

Considerable attention was devoted to reports and comments by representatives of organizations that use oscillographs. N. P. Raevsky, Iu. M. El'kind, V. S. Gusev, D. K. Solpo, M. D. Piven, A. B. Sherman and others talked about general and specific requirements, which are considered necessary for oscillographs of universal and special scopes in recording of electric and nonelectric quantities. Many of the speakers noted that the organization of mass production of the model MPO-2 universal portable oscillographs has made it possible to fulfill the needs of a very wide group of users.

High value was attached also to the designs of universal portable oscillographs models POB-12, POB-14, K9-21, K12-21, K20-2 and 12OC-1. The necessity of further development of production of these models was pointed out, and also the need for development of a modern stationary oscillograph with a charg width of 200-400 mm, with program controlled operations and with a series of numerous accessories.

In many investigations the need arises for recording of processes with frequencies of the order of several thousand cps. For solution of such problems it is necessary in addition to improvement of vibrating oscillographs to use electron-ray oscilloscopes with photographic attachments for recording on a continuously moving ribbon or tape. It was pointed out that such attachments have already been developed and successfully used by a number of

organizations, but that their output in production quantities has not yet been organized.

All speakers, developers are well as consumers, pointed out the need for standardization of metrological characteristics of oscillographs and vibrators, for establishment for them of accuracy classifications and for conducting the necessary research work in the field of metrology of dynamic measurements.

Resolutions were offered for having various types of oscillographs tested by the state institutions of the Committee on Standards, Measures and Measuring Instruments and having them work out standards of basic types and characteristics for oscillographs.

A wide exchange of opinions made it possible for the organizing committee to prepare the following proposals: a proposed nomenclature for magnetoelectric oscillographs, which are necessary to fulfill the requirements of the USSR national economy; a proposed nomenclature for oscillograph vibrators; a proposed subject index of the most important research and engineering papers in the field of oscillograph construction; and a proposed nomenclature for auxiliary equipment needed for oscillographs.

The nomenclature proposal for magnetoelectric oscillographs contains 21 dimension-types, 7 of these for universal instruments and 14 for instruments of special designations. About half of the oscillograph types are still subject to development. There are foreseen oscillographs which encompass the widest scope of technical characteristics, beginning with stationary laboratory apparatus and ending with miniature instruments, made to be placed into test objects. The list of vibrators contains 10 dimension-types of galvanometers of magneto-electric and ferrodynamic systems, of loop type, frame type and radiometer design. The listing is made with consideration of all new achievements in this field, and foresees the production of vibrators with natural frequencies up to 20,000 cps and with various kinds of improved damping systems.

Both mentioned listings represent the first attempted steps on the road of standardization of the characteristics and unification of design of oscillographs and their basic components and constitute a serious practical result of the efforts of this conference.

The list of subjects for research, development and engineering-work approved by the conference foresees the development and production of special lamps and photomaterials, research on utilization of the differentiation and integration properties of frame-type galvanometers (a model of an integrating galvanometer was exhibited at the instrument show), development of standardization data which will establish basic parameters for oscillographs and other projects.

All these problems were reflected in the resolutions accepted by the Conference. These resolutions contain in addition a series of recommendations with respect to organization techniques and also proposals of a more thorough treatment by the press of problems of oscillograph theory and practice and of their applications in various branches of science and industry.

FOURTH PLENARY SESSION OF THE SCIENTIFIC AND TECHNICAL DEPARTMENT'S CENTRAL ADMINISTRATION OF THE INSTRUMENT-MAKING INDUSTRY

M. A. Zborovskii

The Fourth Plenary Session of the Scientific and Technical Department's (STD) Central Administration of the Instrument-Making Industry was held in October 1957.

Deputy Head of the USSR Gosplan's (State Planning Commission) Department for the Electrotechnical and Instrument-Making Industries M. E. Rakovskii reported on the prospects of instrument-making in connection with the reorganization of industrial management. The speaker noted among other things that the output of the

instrument-making industry had increased by a factor of 136 as compared with the pre-war, level, but did not as yet completely satisfy the requirements of the national economy.

According to the decisions of the 20th CPSU (Communist Party of the Soviet Union) Congress, a basis for developing complex industrial mechanization and automation is being set up in our country. In this connection capital investment in the instrument-making industry has considerably increased. The area of plants making computers and instruments for industrial automation will be greatly increased in 1958.

The unifying merger of the USSR Gosplan departments for the electrotechnical and instrument-making industries led to a better and wider use of specialization and cooperation among plants.

In order to improve the technical level of the instrument-making industry a number of new development laboratories and scientific-research institutes were established. At the same time it is planned gradually to build new factories and convert some of the existing enterprises into workshops for experimental work and manufacture of special instruments in small demand designed by the scientific-research institutes and development laboratories. The immediate problem of the instrument-making industry consists in correctly distributing work among the scientific-research institutes and development laboratories.

In its resolution the plenary session drew the attention of the USSR Gosplan to the suggestions made during the discussion of the report:

a) on the desirability of transferring the Scientific-Research Institute of the Weight-Measuring Industry to the control of the USSR Gosplan as a central industrial institute for weight-measuring instruments and testing machines,

b) on the necessity of extending the range of instruments produced in the USSR, especially those for thermal control,

c) on improving experimental facilities for the scientific research institutes and development laboratories,

d) on the desirability of concentrating in the hands of the USSR Gosplan the supervision of the newly established instrument scientific research institutes and development laboratories for at least the period of setting up the organization (2 to 3 years) and the final determination of the scope and scale of their work.

It was also found expedient to:

1) recommend to the Central, Republical and Regional instrument industry Scientific and Technical Department Administrations to keep closely in touch in their practical work with the instrument-industry departments of the USSR and Union Republic's Gosplans, the scientific and technical committees of the USSR and Union Republic Councils of Ministers and technical and economic councils of the Sovnarkhoz in order to adhere to a single technical policy in the sphere of instrument-making,

2) expedite the participation of the instrument-industry Scientific and Technical Departments in informing wide circles of engineers and technicians of our country about the development and production of new measuring instruments and automation equipment by means of conferences, discussions, exhibitions, etc.

THE 2ND INTERNATIONAL CYBERNETICS CONGRESS

The 2nd International Cybernetics Congress organized by the International Cybernetics Association will be held in Namur (Belgium) from September 3 to 10, 1958.

The first congress was held in 1956.

The following questions will be dealt with at the second congress: application of cybernetics to machines, automation and organization of work, economic and social significance of automation, cybernetics and biology, etc.

From May 1958 the International Cybernetics Association is beginning to publish a quarterly journal "Cybernetics." Articles are published either in English or French at the request of the author.

The Secretariat of the International Cybernetics Association is in Namur (Belgium) 13, Rue Basse-Marseilles.

MATERIAL RECEIVED BY THE EDITORIAL BOARD

REPAIR OF STANDARD MEASURES AND INSTRUMENTS

B. L. Sokolov

During the last few years the state inspection laboratories for measuring equipment have been supplied with the latest standard measures, instruments and valuable test equipment, which increased the quantity being checked and repaired at the Institute of the Committee' of Standards, Measures and Measuring Instruments.

The Institutes, however, were not prepared either for their speedy and timely checking or for their repair. Not one of the Committee Institutes' repair and experimental workshops repairs the widely used manometric capsules for loaded-plunger-type manometers of any measuring range. As the result of this valuable measuring equipment cannot be used, and in a number of regions corresponding tests are not being carried out. Formerly the "Etalon" plant in Riga was the only enterprise within the Committee's framework which repaired these manometers. The plant has now been handed over to the Latvian Sovnarkhoz (Council of National Economy) and all repairs by it have been discontinued.

The repair of block gauges and angle gauges is in a similar condition.

The Institutes have not organized the repair in their workshops of the many instruments they check and often pass the repair work on to other institutes or contractors which delays the work considerably.

The nefarious practice of transferring instruments to a lower grade, although forbidden by the Committe as long ago as 1956, is still being practiced.

Organization of the inspection laboratories' reference measures and instrument repairs and the improvement of their repairs by the Institutes deserve the greatest attention on the part of the Committee.

The Institutes must check the instruments rapidly mostly in the presence of the person from the inspection laboratories who brought the instruments for repair. As the result of such an organization of work, the establishments will experience no difficulties in having their instruments checked. This will also considerably reduce wasteful expenditure, since it will be unnecessary to make an additional journey to the institutes for the repaired instruments.

Just as important are the measures for organizing the repair of all the types of standard instruments in the inspection laboratories. It is advisable to organize instrument repairs taking into consideration the specialization of repair and experimental workshops. This will lead to a reduction in the cost of and time spent on repairs.

Finally a system of servicing the inspection laboratories on the spot by adjusters from the Mutual Exchange Bureau should be organized. The absence of travelling adjusting squads impedes the work of laboratories and often leads to damage of valuable instruments. Technical inspection and routine repairs, according to specification and on-the-spot, of mechanical instruments measuring by optical means and precision weighing instruments should be organized within the Committee's framework. This will greatly improve the condition of standard instruments and sets.

It is also necessary to establish repair groups in such distant 1st category inspection laboratories as those of Khabarovsk, Alma-Ata, Irkutsk and Tashkent which are the main laboratories for checking standard instruments of the laboratories in the surrounding districts.

The establishment of an exchange stock of measures and instruments in the Institutes will considerably simplify the organization of repairs. The acquisition by the Institutes' repair and experimental workshops of a

selection of plane-parallel ends distance gauges, flat and plane-parallel glass plates, some of the standard weights including the milligram range, standard electrical instruments which are widely used in inspection laboratories, etc would permit the institutes to repair the instruments more efficiently,distributing the work among the mechanics more evenly.

The financial and economic administrations of the Committee should examine the question of centralized supplying of the repair and experimental workshops with spare parts, materials, etc.

IN THE COMMITTEE OF STANDARDS, MEASURES AND MEASURING INSTRUMENTS

I. NEW SPECIFICATIONS FOR MEASURES AND MEASURING INSTRUMENTS

(Registered in March and April 1958)

New Standards

GOST 3051-58. Pointers of rack-mounted measuring instruments. Types, shapes and dimensions of indicating parts. Technical requirements. Replacing GOST 3051-45.

GOST 3899-58. Electrical contact transducers for checking linear dimensions. Replacing GOST 3899-47.

GOST 5368-58. Instrument for measuring cylindrical gear wheels. Basic technical requirements. Replacing GOST 5368-50.

New Instructions for Checking Measures and Measuring Instruments

Instruction 111-58 on checking goniometers. Replacing section "B" of instruction 49-48 b, for the industrial instrument.

Instruction 147-58 on checking double microscopes.

Instruction 170-58 on checking 2nd-grade standard and laboratory optical pyrometers for measuring temperatures of 900 to 3000°C.

Operating Instructions for Checking Measures and Measuring Instruments Approved by the Committee's Technical Administration

Operating instruction No. 168 on checking micrometer dial gauges with divisions of 0.001 and 0.002 mm.

II. MEASURES AND MEASURING INSTRUMENTS APPROVED BY THE COMMITTEE, AS THE RESULT OF STATE TESTS, FOR USE IN THE USSR

Moving-coil, rack-mounted voltmeters, trade mark M363, made by the Krasnodar plant "ZIP." State register No. 1150-58.

Rectifier rack-mounted ammeters, trade mark Ts25, made by the "Omélektrotochpribor" plant. State register No. 1151-58.

Rectifier rack-mounted ammeters, trade mark Ts26, made by the "Omélektrotochpribor" plant. State register No. 1152-58.

Rectifier rack-mounted voltmeters, trade mark Ts25, made by the "Omélektrotochpribor" plant. State register No. 1153-58.

Rectifier rack-mounted voltmeters, trade mark Ts26, made by the "Omélektrotochpribor" plant. State register No. 1154-58.

Equipment with the trade mark U592, made by the "Tochélektropribor" plant. State register No. 1155-58.

Inductance meters, trade mark IIN-3M, made by the Leningrad plant. State register No. 1156-58.

Electromagnetic inductance meters, trade mark IMI-1, made by the Leningrad plant. State register No. 1157-58.

Measuring lines, trade mark Li-3, made by the Vyborg plant. State register No. 1158-58.

Resonance wavemeters, trade mark VMT-D, made by the Kazan' plant. State register No. 1159-58.

Hydrogeological mercury in glass thermometers, trade mark TM-14, made by the Klin thermometer plant. State register No. 1160-58.

Mercury-in-glass thermometers for normal international 2nd grade elements, trade mark TL-16, made by the Klin thermometer plant. State register No. 1161-58.

Coil-wound instrument resistors, trade mark P310, P321 and P331, made by the Krasnodar plant "ZIP." State register No. 1162-58.

Moving-coil, portable miniature ammeters, trade mark M365, made by the Krasnodar plant "ZIP." State register No. 1163-58.

Moving-coil, portable miniature voltmeters, trade mark M365, made by the Krasnodar plant "ZIP." State register No. 1164-58.

Moving-coil, rack-mounted ammeters, trade mark M358, made by the Krasnodar plant "ZIP." State register 1165-58.

Moving-coil, rack-mounted voltmeters, trade mark M358, made by the Krasnodar plant "ZIP." State register No. 1166-58.

Moving-coil, rack-mounted ammeters, trade mark M362, made by the Krasnodar plant "ZIP." State register No. 1167-58.

Moving-coil, rack-mounted voltmeters, trade mark M362, made by the Krasnodar plant "ZIP." State register No. 1168-58.

Signal generators, trade mark GS-100I, made by the Gor'ki plant. State register No. 1169-58.

Height gauge IZV-1 attachments consisting of surface plates with trade marks ST-5, ST-6, ST-7, and ST-8, made by the Leningrad plant. State register No. 1170-58.

Hydraulic presses with the trade mark PG-100, made by the No. 2 plant of the Moscow City Council of National Economy. State register No. 1171-58.

Calibrated multiplying resistors, trade mark P518, made by the "Tochélektropribor" plant. State register No. 1172-58.

Electricity meters, trade mark I43p, made by the Mytishchinsk plant of electricity meters. State register No. 1173-58.

Electricity meters, trade mark I45p, made by the Mytishchinsk plant of electricity meters. State register No. 1174-58.

Testing presses with trade mark 2PG-250 for static strength-of-materials testing for compression up to 250 tons, made by the Moscow mechanical plant No. 5 of the Glavtonnel'metrostroi USSR Ministry of Transport Construction. State register No. 1175-58.

Mechanical vibrations generators, trade mark GMK, made by the Leningrad plant. State register No. 1176-58.

Capacity asymmetry meters, trade mark IEA-P, made by the Leningrad plant. State register No. 1177-58.

CONFERENCE OF METROLOGICAL WORKERS

B. L. Leonov

Between April 22 and May 30, 1958 the Committee's institutes in Moscow, Leningrad, Kharkov, Sverdovsk and Novosibirsk organized conferences of leading workers in the measurements industry. The conferences were attended by members of the institutes, heads, engineers and technicians of the laboratories assigned to the institutes, heads and engineers of inspection laboratories, and many test laboratories of industrial enterprises and other agencies of administrative control, representatives of the Councils of National Economy and workers in instrument-making and repairing enterprises.

Reports were made at the conference on the fulfilment of the USSR Council of Ministers' decree of October 1, 1955, and on measures taken for the completion of this work; on the activity of the Committee's Institutes and their work of instilling modern measurement techniques and on the work of the State Inspection Laboratories for measuring equipment under the conditions of industrial reorganizations.

In its resolutions the conference noted that due to the fulfilment of the USSR Council of Ministers' decree of October 1, 1955 important successes have been achieved in the development and consolidation of state supervision over measures and measuring instruments, in enlarging the technical scope and competence of the Committee's agencies, whose standing as organizational and technical centers was raised considerably, in improving the composition of the personnel and almost doubling the working areas of the State Inspection Laboratories (SIL).

At the same time important shortcomings were pointed out in the work of the departments and agencies of the Committee, the Institutes and SILs. Thus the institutes lag in certain spheres of measurements; their development work proceeds in some cases inefficiently; some of the SILs' work in enforcing standards and technical specifications and supervising measuring equipment is still at a low level and the assistance rendered them by the industrial departments of the Committee is insufficient; the plan for a centralized supply of SILs with testing equipment has not been fulfilled, as the result of which the laboratories are unable to check some of the measuring instruments; the plan for constructing premises for SIL has not been carried out, etc.

Having noted that the reorganization of industrial management has created favorable conditions for improving the measuring equipment and the methods of its utilization, the conferences paid special attention to problems of reorganizing the work and a further improvement in the state supervision of measuring equipment.

Having noted that the reorganization carried out by the Committee in 1954, which eliminated the overlapping of the state and administrative control, has been completely justified, the conferences approved in principle the further reorganization of work as outlines in suggested rules 12 to 58. The importance of freeing the production personnel of the institutes and SILs from assignments to any particular plant or locality and greatly enhancing the standing of engineers, inspectors and state controllers, providing them with maximum independence and wide possibilities for exerting their initiative, was stressed.

It was noted at the conferences that the cooperation between the institutes and the laboratories assigned to them has improved. However this improvement is insufficient and cannot satisfy the greatly increased requirements of the SILs; the conference resolutions outline specific measures for the improvement of links between the institutes and the SILs.

It was found imperative to pay special attention to collective farms and district tractor stations which are now supplied with all kinds of modern equipment, including measuring instruments.

Many critical remarks were passed at the conference regarding the low quality of some of the measuring instruments; the conference resolutions include suggestions for the elimination of these defects. The importance of systematic testing by the instrument-making plants of their production, especially for length of life under working conditions, was particularly stressed.

The conferences noted that in order to speed up the work of SILs it is necessary to establish a close contact between them and the Scientific Research Institutes, Regional Inspection Bureaus and enterprises making measuring instruments on the territory served by the SILs, to shorten the time for preparing prototypes of new measuring instruments, especially the time of putting them into mass production, and to control more strictly the timely submission of measuring instruments for state testing.

The conferences recommended the establishment of a routine by which enterprises wishing to submit instruments for state testing should work out test specifications for their own instruments. These specifications will be taken into consideration when the Committee's institutes work out appropriate instructions and methods of testing.

Considerable attention was paid in the conference resolutions to the selection and training of personnel, improving technical information, perfecting the new testing equipment and devices with the object of raising their productivity, decreasing their size, and enlarging the production of standard instruments.

In order to raise the technical standard of the SILs it was considered advisable to entrust certain SILs with simple experimental research work, development of portable equipment, state testing of instruments, etc.

The repair of measures and measuring instruments in our country is still unsatisfactory. The conferences decided to promote the strengthening of small repair shops and to establish enterprises for the repair of measuring instruments of various types. This will improve the technique of servicing, lower the cost, provide a better utilization of repair specialists, etc.

As the result of the conferences, a unity of opinion of the metrological workers has been established with respect to the present condition of the measurement techniques in the country and with respect to the correctness of the principles laid down for the reconstruction of measuring methods.

There is no doubt that the fulfilment of the decisions adopted at the conferences of leading metrological workers will lead to the elimination of defects in state and departmental inspection of measuring equipment and to the raising of the measurement techniques to a higher level.

CONFERENCE ON EVALUATING WHITENESS

E. N. Iustova

An enlarged meeting of the Colorimetric Commission of the D. I. Mendeleev All-Union Metrological Scientific Research Institute was held in February 1958 to discuss the problem of measuring whiteness.

Over 40 representatives of various organizations took part in the conference.

The conference had as its object to specify the concept of "whiteness," critically review the methods and instruments used for that evaluation, clarify the state of the art both here and abroad, examine the possibility of developing further the measurements of whiteness, and coordinate the work of various organizations in this connection.

Papers were read and information supplied on methods of measuring whiteness; on the electronic color comparator and its application for measuring whiteness; on the photometer FT-2 and its use for the same purpose; on the search for a rational method of measuring the whiteness of marble; on the development of whiteness measurements abroad; on the significance of the concept of "whiteness" in sorting commodities; on the latest models of laboratory and shop-testing instruments allocated for mass production, such as the laboratory model of Demkina's (TTsK) three-color colorimeter, the differential spherical photometer (FM-58), the modernized photometer (FM-56), the photoelectric comparator GOI; the experience in checking whiteness and evaluating the color of paper, etc.

The majority of speakers noted the uselessness of the photometeric brightness coefficient for evaluating whiteness and the abnormal lack of shop-testing instruments for measuring small color differences (color comparators) and the insufficient quantity of KNO colorimeters and simplified FT-2 spectrophotometers.

The necessity of developing new standards of whiteness with a known spectral reflection and the establishment for each industry of their standard production-testing whiteness scales was noted.

It was agreed at the conference that the concept of "whiteness" is used in industry and everyday life in two meanings: in the first place as the evaluation of the material or article by the pleasant impression of cleanliness it produces and in the second place as an indirect indication of the physical properties of the material. In either case for measuring whiteness it is necessary to use the colorimetric of spectrophotometric technique.

For the spectrophotometric evaluation of whiteness it is possible to use instrument FT-2. A colorimetric approach required highly sensitive color comparators whose manufacture has not yet been organized. Hence it is imperative to insist on speeding up the production of the comparator developed by the GOI.

In connection with the lack of instruments, the conference entrusts the Colorimetric Commission Bureau to approach the USSR State Planning Commission with the request to organize the production of several types of instruments: to start with a simplified spectrophotometer FT-2 and a direct-reading calorimeter (KNO-3) and, after the completion of development and the passing of the state tests, the production of such instruments as the spherical photometer FM-58 and the photoelectric color comparator GOI.

In order to improve and develop the methods of measuring small color differences, the conference recommended continuing the scientific research work in close contact with industrial enterprises.

The permanent Colorimetric Commission was asked to coordinate the studying of whiteness and to request the establishment of a center at the All-Union Metrological Scientific Research Institute, equipped with the latest models of instruments for measuring and evaluating whiteness and able to provide the required testing and investigation of problems submitted to them by industrial organizations.

THE ALL-UNION D. I. MENDELEEV INSTITUTE OF METROLOGICAL RESEARCH ANNOUNCES ACCEPTANCE OF ASPIRANTS IN THE FOLLOWING SPECIALTIES

ELECTRICAL MEASUREMENTS
RADIOTECHNICAL MEASUREMENTS
ACOUSTICAL MEASUREMENTS
MEASUREMENT OF IONIZING RADIATIONS

As aspirants are accepted persons who have completed their university education and have had not less than 2 years' experience in laboratory or practical work in their chosen specialty.

Applications must be made before October 1, 1959, to the director of the All-Union D. I. Mendeleev Institute of Metrological Research with enclosure of the following papers in duplicate:

1. Autobiography
2. Personal worker's enlistment card.
3. Copy of university diploma, verified by a notary, with a transcript of subjects and grades.
4. Photographs.
5. Statement on status of health.
6. Testimonial from working place.
7. List of research papers and inventions.

Persons who do not have published papers or inventions present a review in their chosen special field.

For applicants to aspirantship there are established entrance examinations within the scope of the entire course of the following three subjects:

1. History of the Communist Party of the USSR.
2. A foreign language.
3. The special subject.

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